Author and student. (*Courtesy of California Polytechnic School.*)

(*Frontispiece.*)

Arc and Acetylene Welding

BY

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FIRST EDITI(
SECOND IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1944

ARC AND ACETYLENE WELDING

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

This is a nontechnical book on acetylene and electric welding designed for the beginning student or for the instructor or engineer who understands the technical but not the practical side of welding. It is not an outline of a welding course but a text presenting the in-between steps of welding technique necessary to make the 110 per cent weld. These steps are usually learned by the welder after years of experience by the trial-and-error method.

This book may be used in a trade or vocational class. The student, by thoroughly familiarizing himself with the material presented here, will shorten his training period and eliminate many hours of useless practice spent on the wrong procedure. With the aid of this book a beginner should be able to teach himself to weld.

Much emphasis is placed upon technique. If the rod and torch or electrode are held in the proper position and advanced with the correct movement, the result will be a strong, smooth deposit, or weld. If an incorrect technique is used, the weld, or deposit, will be poorly fused, incorrectly formed, and, in general, unsatisfactory. The weld metal will go exactly where the student places it, not necessarily where he wishes it to go.

With no instruction whatever the student may work out a technique of sorts and in time overcome most of his errors. But learning by the trial-and-error method is slow and costly and in many cases produces the unfortunate attitude of excusing poor welds or accepting them as a matter of course. After the student becomes proficient in welding, he will undoubtedly personalize

his technique. However, by that time he will have learned the common pitfalls and how to overcome them.

While much emphasis is commonly placed upon the equipment, materials, and technique of the welding trade, in the final analysis it is the welder using these implements who has the responsibility of making a good weld. The welder's pledge should be studied and its principles rigidly followed.

The student must remember that all welds must be 110 per cent strong. The weld must be stronger than the parent metal. If a weld breaks, the welder is at fault. When a weld is completed, the welder knows whether or not it is good. If the weld has a weak spot in it, then, regardless of the time lost or the expense involved, it must be cut out and rewelded.

Undue speed is often the demand of those unfamiliar with welding, those who do not understand the time, trouble, and skill necessary to make the 110 per cent weld. Remember, the quality of the weld is the important thing. The broken weld is remembered long after your speed is forgotten.

It is to the student's advantage to learn a method by which he may control the weld puddle at all times. The method to be discussed is applicable to the welding of all metals. First discussed is the method of acetylene welding. The principles learned during this discussion will aid the student in his understanding of all types of welding. Over a long period of experimentation, it has been established that a student with a background of acetylene welding has little difficulty in mastering arc welding.

Arc welding involves the same principles as acetylene welding. In both methods, the edges of the joint must be melting and flowing while the filler rod, or electrode, is added to the puddle.

The action of the weld puddle under the acetylene flame is easily seen since the flame that is melting the plate and the rod used as a filler are separately controlled. With the arc-welding process the melting of the plate and depositing of the rod are under a single control

Poor fusion or penetration is not so easily detected in welding with the arc as in the acetylene process. But if the electrode is advanced with the correct technique and if enough welding heat is maintained on the welding machine thoroughly to melt and fuse the base plates, the 110 per cent weld may be developed.

The primary test plates and exercises will be on light-gauge metals. There are a number of reasons for this. All students, regardless of their ultimate goal in the field, must learn to weld. This action involves technique, ability to recognize the quality of a weld, attention to the finished surfaces of the weld, and knowledge of the common faults of welding—undercuts, gas pockets, slag holes, lack of fusion, and lack of penetration. It is simpler and more economical for the student to learn these principles while using a small welding rod and a light-gauge metal. The method learned with these materials will apply to heavy-duty and high-pressure welding, and the student, without learning a new technique, will be able successfully to weld heavy material. Moreover, he learns faster on light material, the dangers of burns are lessened, and the waste of material used in practice is at a minimum.

When the student has finished the first five plates, he has learned what actually constitutes a weld. The succeeding plates are merely advanced applications of the very thing he has mastered.

HARRY KERWIN.

SAN LUIS OBISPO, CALIF.,
June, 1944.

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PART II

ARC WELDING

THE WELDER'S PLEDGE[1]

I, ______________________________, desire to be known as a *first-class welder*. I understand the obligations and responsibilities placed upon me. I realize that great property damage and possibly loss of life may result from a poor weld. Therefore I pledge myself to the following articles:

1. Never to be guilty of knowingly making a poor weld.
2. To report immediately to my superior any weld that I believe is not thoroughly dependable for the service for which it is intended.
3. To do all in my power to advance the cause of welding.
4. To give my employer, at all times, my best effort, loyal service, and honest workmanship.
5. To strive each day to increase my knowledge and skill in the art of welding.
6. To extend all possible assistance to welders less proficient than myself.
7. Realizing that appearance as well as quality is important in a weld, always to strive to improve my workmanship.
8. Always to be punctual.
9. To the best of my ability to work in harmony with my fellow workers.
10. To expect a wage commensurate with my ability.

[1] With acknowledgments and thanks to the Lincoln Electric Company.

PART I

Acetylene Welding

CHAPTER I

THE WELD

To make a weld by either the acetylene or the arc-welding process means to melt and flow together two or more pieces of metal to form one strong, tight, clean metal.

Two important factors, fusion and penetration, must operate in every weld to ensure a 110 per cent job. *Fusion* means the actual melting and fusing of the metals. *Penetration* means the depth to which fusion is obtained. In the welder's language, penetration means the distance or depth to which fusion has reached through the joint and whether or not the bottom edge of the joint is welded.

To obtain full fusion and penetration it is necessary, on any metal heavier than ⅛ in., to bevel or scarf the edges to allow the joint to be welded completely through.

The quality of a weld cannot be judged entirely from its outside appearance. Figure 1 shows an iron bar broken in two through the center. If the pieces of the bar were pushed tightly together and a weld made around the outside, it would appear to be a good job. But if this bar were put in service, it would fail, for the inside is unwelded.

In Fig. 2 the same bar has been beveled for welding. This may be done with either the cutting torch or the grinding wheel. The bevel may be cut with an angle

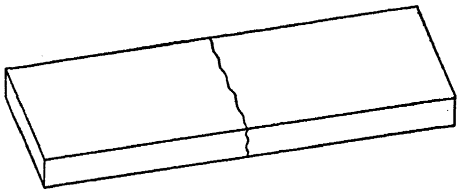


FIG. 1.—Bar broken in two pieces.

of 30 to 40 deg. This allows room to begin the weld at the bottom edge of the joint in order to weld all the way to the top with full fusion and penetration.

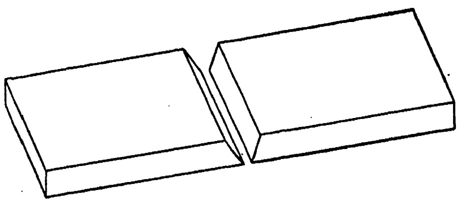


FIG. 2.—Bar beveled for welding.

It is possible to have penetration with insufficient fusion. In Fig. 3 the joint is apparently welded all the way through. There seems to be a weld on the top and on the bottom. But a close examination of the figure

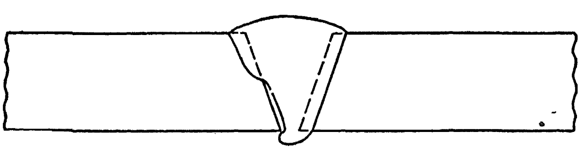


FIG. 3.—Apparently full penetration, but left bevel shows poor fusion.

shows that there is no fusion on the inside bevel, or the side next to the welder. This is a frequent fault of the beginner. This side of the joint is partly out of the welder's vision, and the weld metal instead of being

fused well into the bevel is plastered into it. This joint will fail.

In Fig. 4 the same joint is well fused into each side, with a smooth bead on top. But here the penetration is poor. The weld has not reached the bottom edges of the joint. Under strain, a fracture will develop through the unwelded portion.

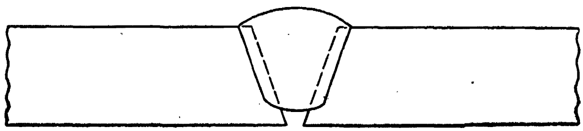


FIG. 4.—Poor penetration. The weld has not completely penetrated the joint.

Figure 5 shows the joint properly welded. It has good fusion and penetration and a smooth weld on the top. This weld may be termed 110 per cent. The welded area will withstand more strain than the parent metal.

The size of the weld does not necessarily indicate the strength. If the deposit fills the vee, if there are

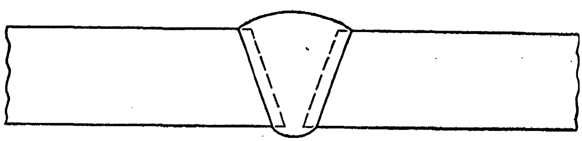


FIG. 5.—Perfect fusion and penetration.

good fusion and penetration, and if the deposit is not over ⅛ in. above the plate, then the weld will withstand the maximum strain. It would be of no advantage to pile the weld metal higher upon the plate. The strength of the metal would probably be impaired owing to the excess heat applied to the weld in adding the extra metal. In any case, excessive thickness in a weld is a waste of time and material.

CHAPTER II

WELDING EQUIPMENT

The oxygen bottle, or tank (Fig. 6), is a thin-walled cylinder made from the highest grade steel. The size most used is about 56 in. tall and weighs about 148 lb. This bottle holds 220 cu. ft. of oxygen at 2,000 lb. pressure when full.

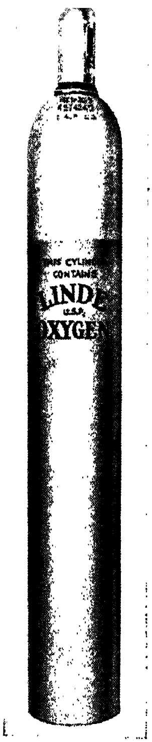


FIG. 6.—Oxygen bottle. (*Courtesy of Linde Air Products Co.*)

There are several rules for handling oxygen bottles that must be strictly obeyed:

Keep the cylinders away from all fire. Do not expose the cylinders to heat.

Keep all oil and grease away from the oxygen cylinder. Oxygen unites very readily with oil or grease, often explosively. Do not handle oxygen bottles or hose with oily gloves. Do not place the cylinder in a corner where oil dust may gather.

Do not use oxygen as compressed air to blow out oil tanks or oily dust. Do not inflate automobile tires with oxygen.

Use oxygen only for the purpose for which it is intended, in this case welding or cutting.

When in use the bottle should be erect (Fig. 7). It must be fastened securely to prevent its falling or being knocked over. If it is impossible to fasten the bottle in an erect position, lay it flat on the floor or ground, placing blocks on each

side of the bottle to prevent rolling and damage to the regulator.

When in use the valve on the oxygen bottle should be completely open. There is a seat in the valve that closes to prevent leaks when the valve is fully open

FIG. 7.—Fasten oxygen bottle to acetylene tank. (*Courtesy of Linde Air Products Co.*)

(Fig. 8). Opening the valve part way may result in wasted oxygen.

The carbide generator (Figs. 9 and 10) produces acetylene gas. The carbide, which is composed of coke and lime, is placed in a container in the top section of the generator, and the water is placed in the lower section. Carbide upon contact with water generates acetylene gas. The flow of carbide into the water is automatically regulated by pressure.

Keep all pop-off valves on the generator in good working order.

Keep the flash-back tank filled to the proper level.

Always empty and flush out the generator every time a charge of carbide is added.

Always place the water in the generator first when charging a carbide generator.

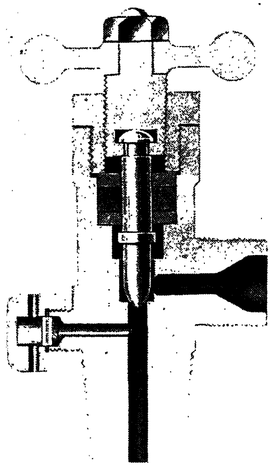


FIG. 8.—Oxygen cylinder valve. (*Courtesy of Linde Air Products Co.*)

Never overcharge a generator; that is, do not use more than 1 lb. of carbide to 1 gal. of water.

Always keep all lights, fire, or sparks away from a carbide generator.

The acetylene tank (Fig. 11) is occasionally a more practical gas dispenser, although it is more economical to use acetylene gas directly from the carbide generator.

Acetylene gas is placed in tanks by the commercial manufacturer, who dissolves the gas in acetone. Acetone has the ability to absorb 14½ times its own weight in gas. After the acetone is in the tank, it releases the acetylene

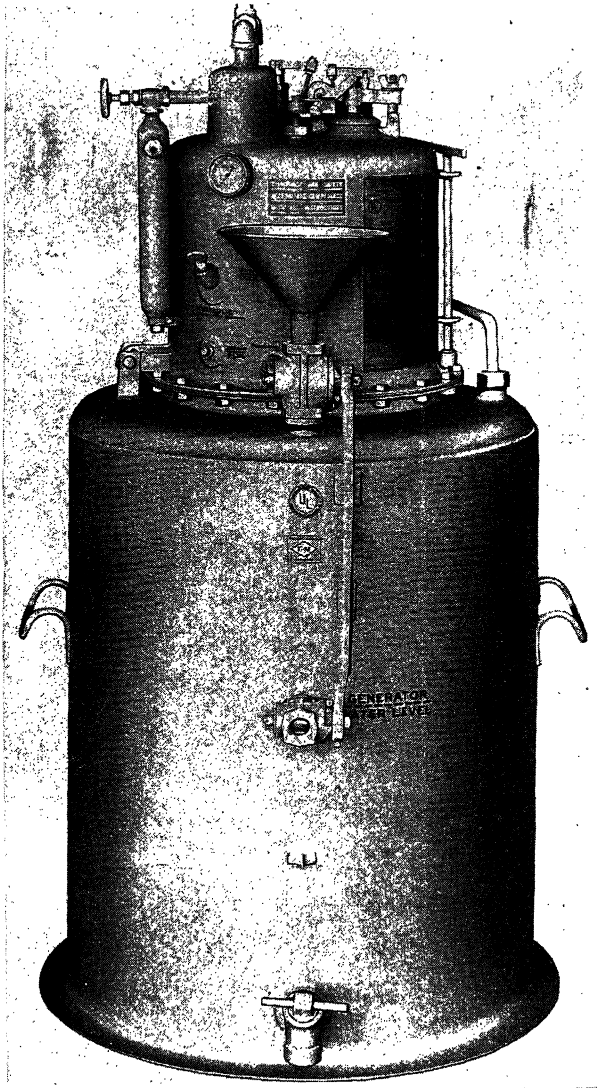


Fig. 9.—Portable type of carbide generator. (*Courtesy of Linde Air Products Co.*)

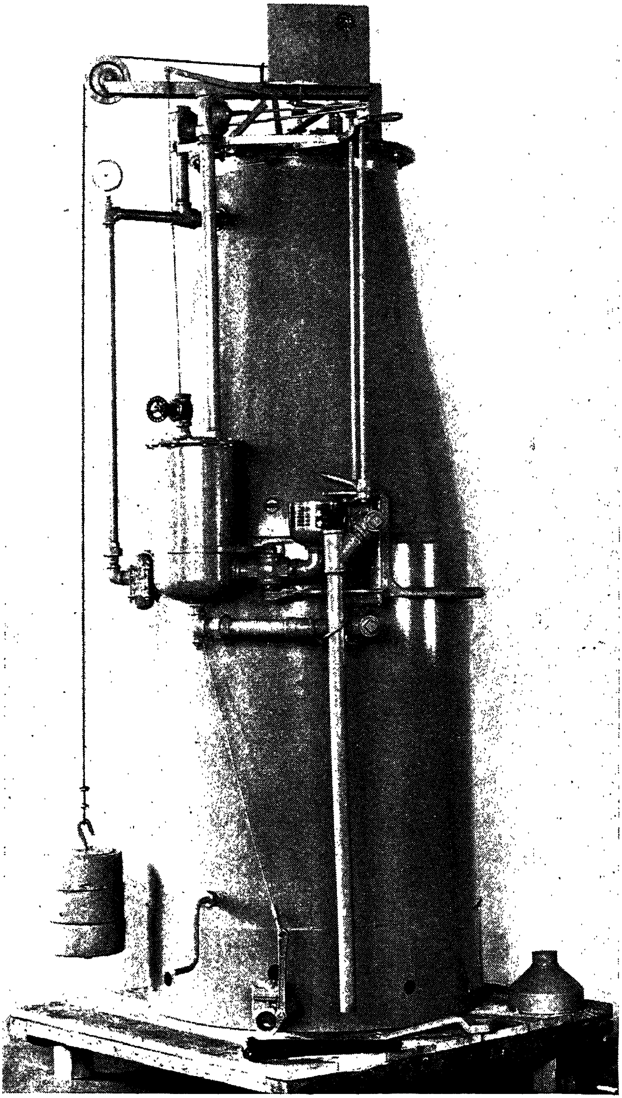


FIG. 10.—Carbide generator, stationary type. (*Courtesy of Air Reduction Sales Co.*)

gas. The gas filters through a porous filler to the top of the tank, where it is drawn off through the tank valve (Fig. 12).

The tank must be erect while in use. The valve should be opened only half a turn when the tank is in

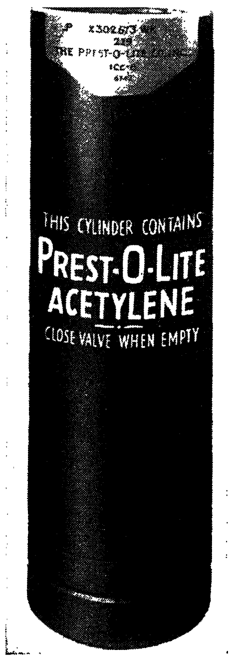


FIG. 11.—Acetylene tank. (*Courtesy of Linde Air Products Co.*)

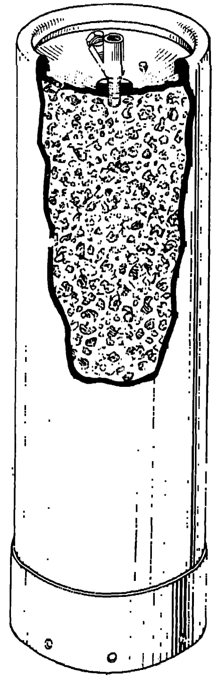


FIG. 12.—Cutaway section of an acetylene tank. (*Courtesy of Linde Air Products Co.*)

use. The tank must be handled gently and must never be subjected to fire or heat.

The regulators are of two types, the two stage and the single stage. The two-stage oxygen regulator (Fig. 13) has two gauges. One gauge registers the contents of the cylinder and shows 220 cu. ft. at 2,000 lb.

pressure. The other gauge registers the pounds pressure within the welding hose.

The acetylene regulator has two gauges, one registering the cubic contents of the tank and the other the pounds pressure on the welding hose.

The single-stage regulator (Fig. 14) has only one gauge. This registers pounds pressure on the welding hose.

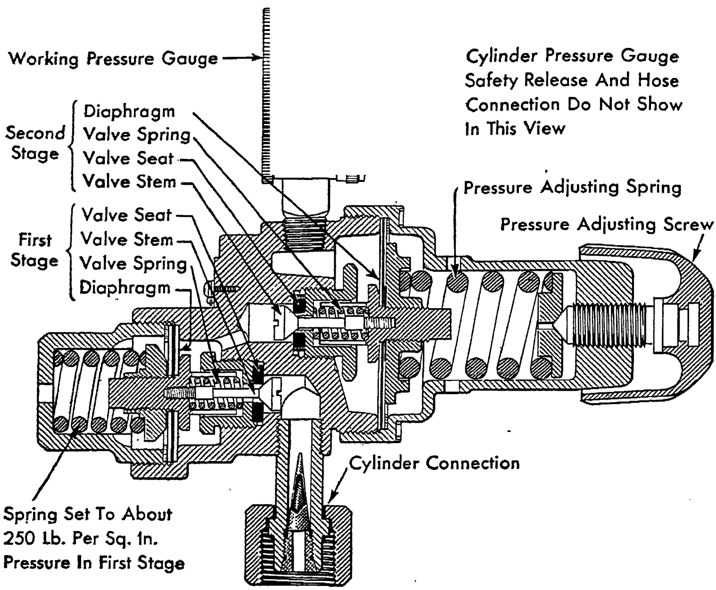


FIG. 13.—Two-stage regulator. (*Courtesy of Linde Air Products Co.*)

This regulator is of light construction and is generally used as a line gauge in the shop, where the pressure will not exceed 10 lb.

The welding torch, or blowpipe, is designed to produce a welding flame, composed of oxygen and acetylene gases, under perfect control. While welding torches vary greatly in general size and appearance, they have the same principles of construction.

The welding torch, or blowpipe, has two valves at one end to which the oxygen and acetylene hoses are attached. The oxygen and acetylene pass through the valves into separate tubes contained in the handle of the torch. The gases flow up the tubes to the opposite end of the torch into a mixing chamber. Here the gases are thoroughly mixed in the proper proportion and flow

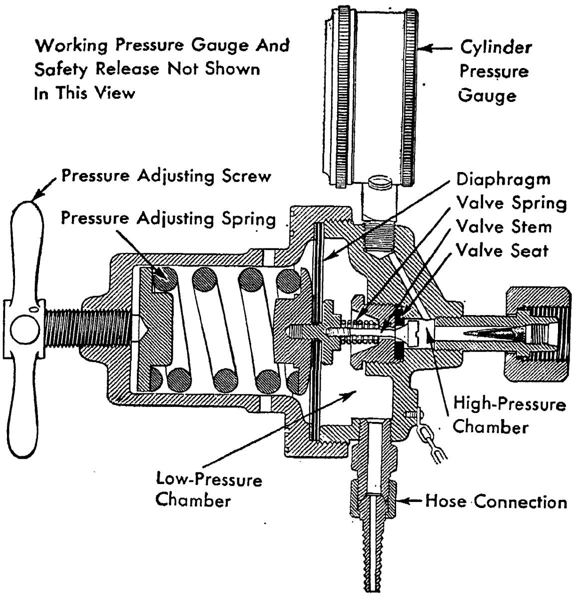


FIG. 14.—Single-stage regulator. (*Courtesy of Linde Air Products Co.*)

out the welding tip as one gas. This gas, when ignited at the end of the tip, gives off a flame of great heat. The end of the torch containing the mixing chamber is the head of the torch. It is threaded, and different-sized welding tips may be attached to the torch by means of a head nut (Fig. 15).

The welding torch may be transformed into a cutting torch by removing the welding tip and replacing it with a cutting attachment.

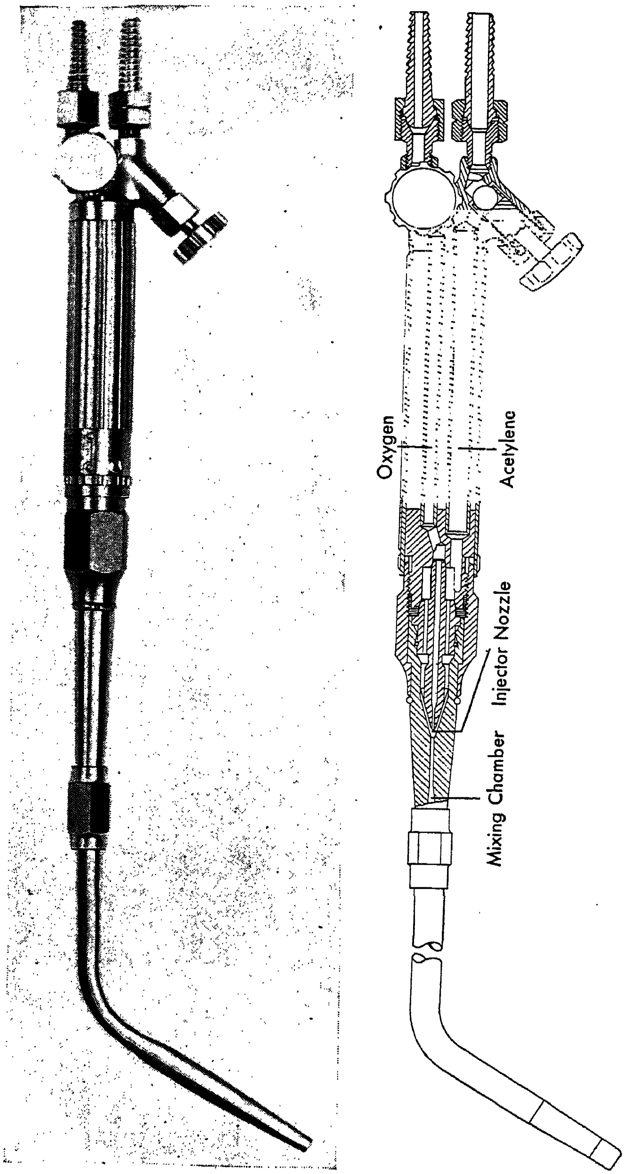


Fig. 15.—Welding torch. *(Courtesy of Linde Air Products Co.)*

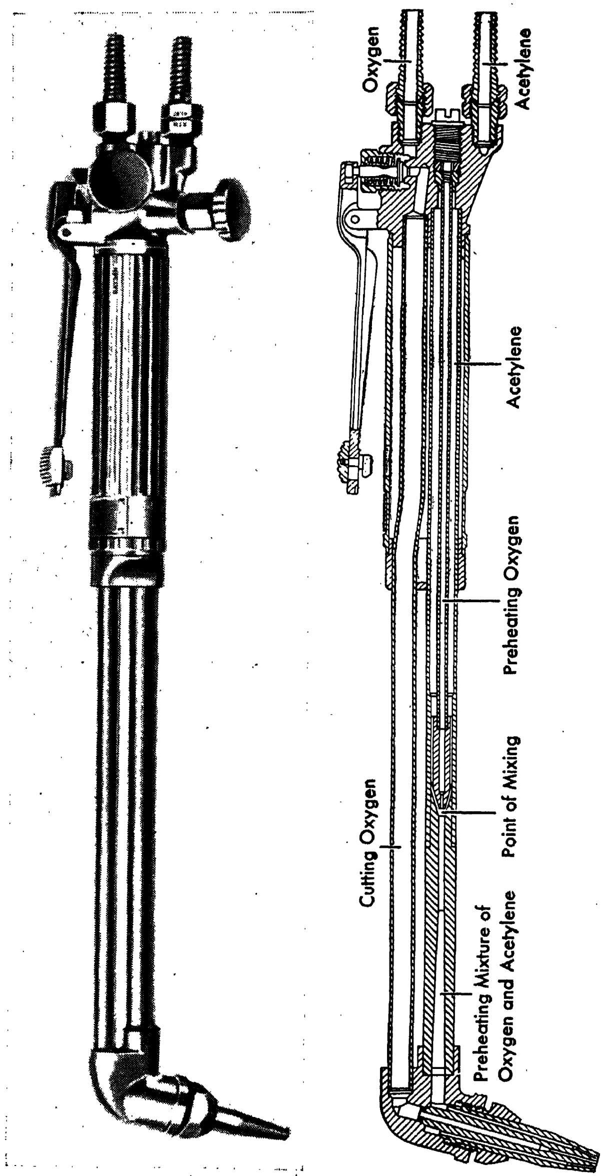


FIG. 16.—Cutting torch. (*Courtesy of Linde Air Products Co.*)

Welding-tip sizes and welding pressures are not standardized. The welding tips mentioned here (Victor Equipment Co.) may be used as a basis of comparison.

The cutting torch (Fig. 16) is closely related to the welding torch in its general construction, having one

FIG. 17.—Cutting a crankshaft. (*Courtesy of Linde Air Products Co.*)

tube for oxygen and one for acetylene. In addition, it has an extra tube, a high-pressure oxygen tube, running parallel with the other tubes. Oxygen is released through this tube to the center hole in the cutting tip by pressing down the high-pressure lever.

The oxygen and acetylene gases flow through the tubes to a mixer, where they are combined into one gas.

From the mixer this gas passes through the outside circle of small holes in the cutting tip. These small streams of gas when ignited become the preheating flame.

The cutting torch is lighted and adjusted in the same manner as the welding torch to secure a neutral flame. The cutting pressure must be adjusted according to the thickness of the material.

In making the cut, adjust to a neutral flame. Hold the torch in such a position that the preheating flames just miss the pieces to be cut. When the area under the cutting tip becomes hot enough to begin sweating, press the high-pressure oxygen lever. This stream of oxygen will unite with the hot metal, causing the metal to burn. The force of the oxygen stream directed against the cut will blow away the burned material (Fig. 17).

The torch should be held at right angles to the piece being cut, with the cutting tip pointing slightly forward in the direction of the cut. This position allows the preheating flames to play upon the uncut portion and heat it before the high-pressure oxygen stream is applied.

If the tip holes become plugged or partly stopped, as they will in the course of normal use, the holes should not be cleared with wire, nails, or files. Regular tip drills should be used to clean the holes properly.

The cutting torch should not be used as a hammer. If a clean cut is made, the cut piece will drop. The tip should not be scrubbed on the table or on any iron or brick surface. The tips are made of soft copper, and it is easy to batter the holes in them until it is impossible to make a good cut.

The stream of sparks and hot particles of metal flying from the cut should be directed so that they will not fall

upon other equipment, cable, or hose. The operator should take care that the sparks do not fall into his own cuffs or shoes (Fig. 18).

If these precautions are observed, the dangers of fire, explosion, ruined equipment, and personal injury will be largely eliminated.

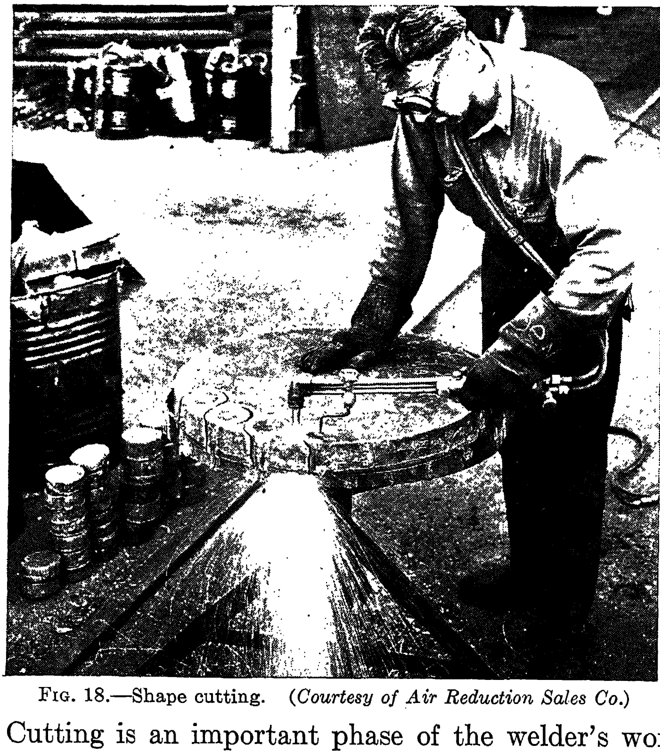


FIG. 18.—Shape cutting. (*Courtesy of Air Reduction Sales Co.*)

Cutting is an important phase of the welder's work. The quality of a weld, the ease of making a weld, and the speed of welding definitely depend upon the cutting and fitting of the joint. The welder is handicapped when he cannot cut well. It means loss of important time and labor when the welder cannot cut and fit his own work and properly use the cutting torch.

CHAPTER III

PREPARATION FOR WELDING

Setting Up the Welding Outfit.—To set up the welding outfit stand the acetylene tank upright near the work-bench, but not so close that the sparks or heat will come in contact with the tank. Stand the oxygen bottle beside

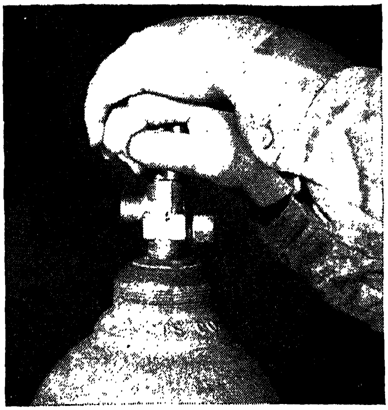


FIG. 19.—Open valve. (*Courtesy of Linde Air Products Co.*)

the acetylene tank and fasten them so that they cannot fall (Fig. 7).

Remove the protector cap from the oxygen bottle, and open the valve slightly to blow out any dust or foreign matter (Fig. 19). Fasten the oxygen regulator to the oxygen cylinder (Fig. 20). Use the gauge wrench to tighten the connection. Do not fasten too tightly.

Fasten the acetylene regulator to the acetylene tank (Fig. 21). Fasten the welding hoses to the regulators. The welding hoses are of different colors so that they will not be confused. The oxygen hose is green, with right-

FIG. 20.—Fastening oxygen regulator to cylinder. (*Courtesy of Linde Air Products Co.*)

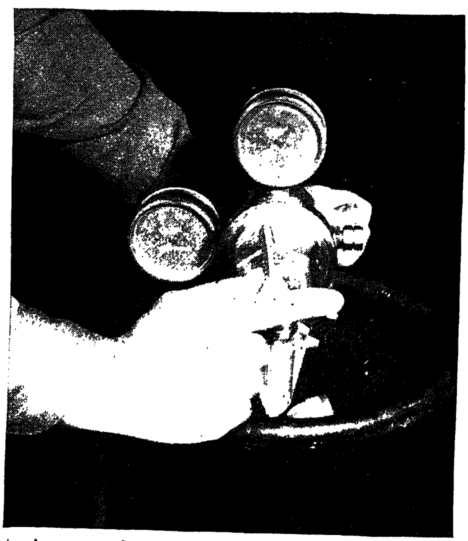


FIG. 21.—Fastening acetylene regulator to tank. (*Courtesy of Linde Air Products Co.*)

hand connections. The acetylene hose is red, with left-hand connections. The acetylene connections have a

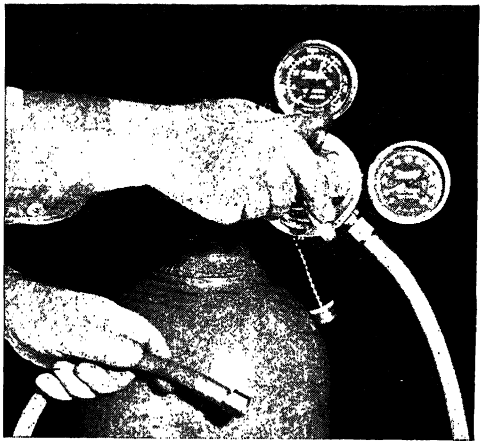


FIG. 22.—Blowing dust from hose. (*Courtesy of Linde Air Products Co.*)

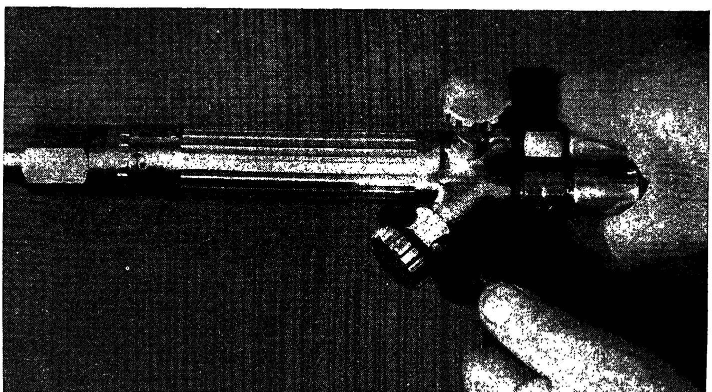


FIG. 23.—Fastening welding barrel to hose. (*Courtesy of Linde Air Products Co.*)

groove cut in the outer surface for further identification.

Open first one tank, then the other, and blow out both hoses (Fig. 22). Close the tanks, and fasten the welding torch to the other end of the hoses (Fig. 23).

Select a welding tip size No. 2, and fasten it to the welding torch with the tip pointing toward the side that has the acetylene valve. When the torch is placed upon the bench, the two valves should be up. The soft tip

FIG. 24.—Welding tip points toward acetylene valve. (*Courtesy of Linde Air Products Co.*)

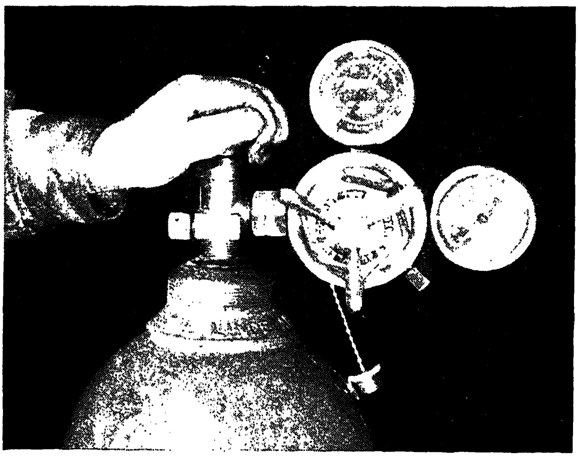


FIG. 25.—Turning on oxygen cylinder. (*Courtesy of Linde Air Products Co.*)

should point slightly up so that it will not be damaged when in contact with the bench (Fig. 24).

Check all regulator and hose connections to be sure that they are tight. Turn the oxygen-cylinder valve on as gently as possible (Fig. 25).

Make sure that the regulating screw is loose in the regulator. If this screw is left tight, the high pressure

rushing into the regulator will pass into the low-pressure side and will be more than likely to rupture the diaphragm in the regulator. There is also the possibility of the gauge blowing apart under the sudden strain. In turning on the oxygen-cylinder valve stand to one side, and do not reach over or around the regulator.

FIG. 26.—Testing welding hose. (*Courtesy of Linde Air Products Co.*)

After the pressure has reached its maximum, continue opening the valve until it is completely open. Open the acetylene tank valve with a T wrench, one-half turn only. Open the oxygen valve on the torch, and turn the regulating screw in the oxygen regulator slowly to the right, until 2 lb. pressure has been reached on the hose pressure side. Then close the oxygen valve on the torch.

Open the acetylene valve on the torch, set the acetylene pressure at 2 lb., and then close the acetylene valve on

the torch. The regulator pressures for welding are judged by the welding-tip size.

If the torch is not to be used for half an hour or longer, release the pressure on the gauges.

The welding hose should be rolled and hung up when not in use. Keep the hose away from oil and grease. When in use the hose must be placed where sparks and hot metal cannot fall upon it and where it will not be

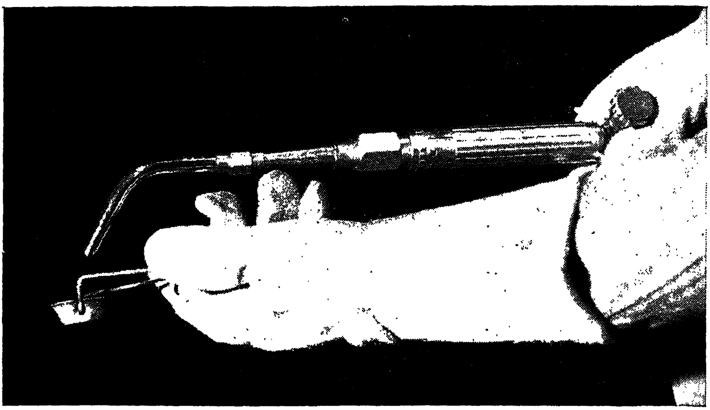


FIG. 27.—Lighting torch. (*Courtesy of Linde Air Products Co.*)

stepped on. At least once a week check the hose for leaks (Fig. 26). If a hose becomes cut or burned, repair it with hose splicers. Do not tape a burned or broken hose.

Lighting and Adjusting the Torch.—With the pressures set at 2 lb. on each regulator, open the acetylene valve about one-half turn, and ignite the gas at the end of the tip with a friction lighter (Fig. 27). Then turn the acetylene on until the flame does not smoke or until it just leaves the tip (Fig. 28). Now turn the oxygen on slowly. The flame will brighten and draw down to the tip. Add oxygen until there is a white inner cone sur-

rounded by a ragged feathery edge of acetylene (Fig. 29). Then turn the oxygen on until the featheredge disappears.

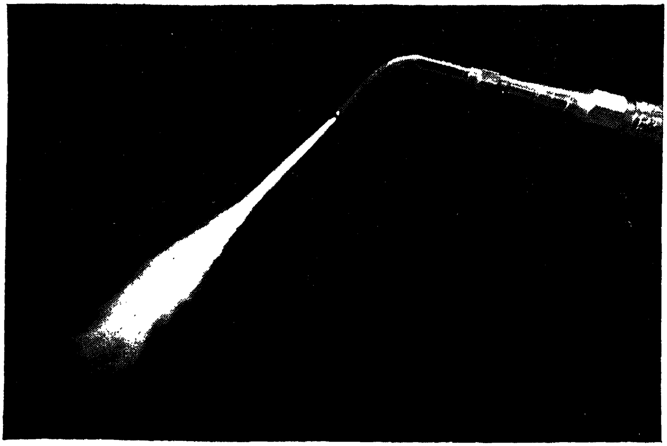


FIG. 28.—Adjusting flame. (*Courtesy of Linde Air Products Co.*)

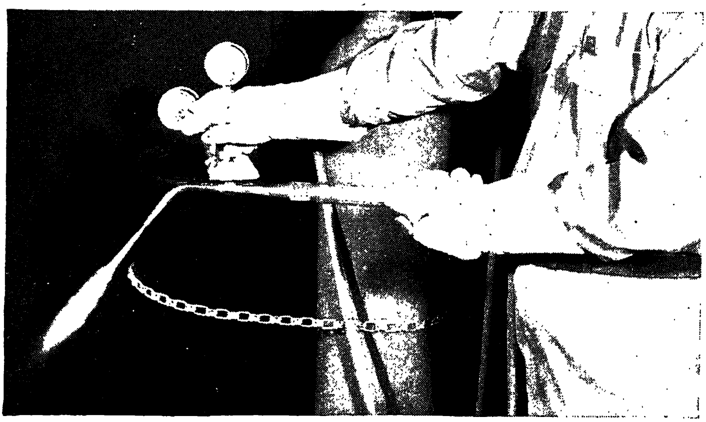


FIG. 29.—Adjusting flame. (*Courtesy of Linde Air Products Co.*)

This flame is called a *neutral flame* (Fig. 30) and is the one that will be used for all mild-steel welding.

If more oxygen is added, the flame becomes an oxidizing flame. Each flame has its own puddle characteristic.

The neutral flame that will be used for the present makes a clean, smooth puddle with no sparking (Fig. 31).

FIG. 30.—Neutral flame. (*Courtesy of Linde Air Products Co.*)

The featheredged flame, having an excess of acetylene, deposits carbon. In welding mild steel the puddle will

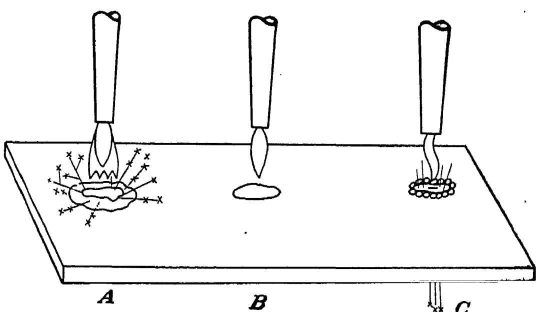


FIG. 31.—*A*, carbonizing flame, excess acetylene; *B*, neutral flame; *C*, oxidizing flame, excess oxygen.

have a thick scum over it, accompanied by excessive sparking (Fig. 31).

In closing the torch, always turn the acetylene valve off first. This will prevent the acetylene gas burning back into the tip and depositing carbon.

If, during welding, the torch makes a popping sound, the flame goes out, and a whistling noise occurs, turn both torch valves off as fast as possible and allow the torch to cool before resuming the weld. However, if the torch makes an occasional popping sound and the flame continues to burn, select a size smaller welding tip to continue the weld. If the flame continually blows away from the tip during welding, select a size larger tip to continue the weld.

CHAPTER IV

BASIC PRACTICE PLATES

Lesson 1

Making a Penetration Bead on a Flat Plate

Since you must have the penetration under perfect control at all times, the first practice plates will deal primarily with the penetration bead. In the first lesson

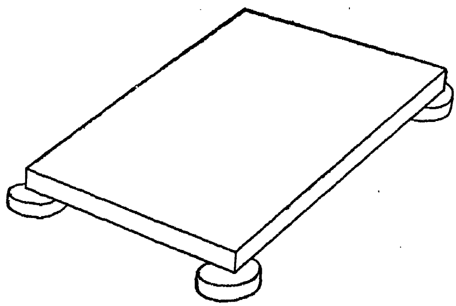


Fig. 32.

you will learn to judge the depth of penetration and how to secure as much or as little as you desire.

Use 18-gauge black-iron scraps for practice pieces. Select one piece about 5 in. long and about 3 in. wide. Place this upon the welding bench. Place two pieces of metal or brick under the plate to suspend it above the table at least 1 in. (Fig. 32). If the practice plate rests flat upon the table during welding, the steel or brick surface of the table top will act as a cooling agent and draw the heat from the practice plate into the table. This is not desirable, for the drawing action will cause

the bottom of the weld or the penetration bead to be "mushy."

When you are ready to weld, you should be seated in a comfortable position at the welding bench. Sit with your back straight, and lean forward slightly to permit free arm movement. The top of the welding bench should be about level with your belt buckle. An experienced welder can make a weld in any position and in very cramped quarters, but the amount of work he can produce will be increased if he can work in a comfortable position.

Welding tires the beginner rapidly. However, if at regular intervals, you shut off the torch, rise and stretch, and flex the fingers and swing the arms, you will find that the tension will be relieved. After a short period of practice, you will learn to adjust yourself to the various positions and will not tire so easily. Make yourself as comfortable as possible, and better work will result.

Using a No. 1 welding tip for this exercise, adjust the oxygen and acetylene pressures to 1 lb. each. Adjust the goggles. The headband on the goggles should pass around the head close to the ears and under the curve of the back of the head. They should fit snugly but not tightly; they must not swing away from the face as you bend over your work, but if they are too tight, a headache will result. Adjust the spacing links so that the goggles will fit closely to the face at the nose.

Light the torch, and adjust it to a neutral flame. Hold the torch in the right hand, if right-handed. Hold the welding hose in the left hand about 18 in. back from the torch. This will prevent the weight of the hose dragging on the torch. Hold the welding torch so that it is at right angles to the line of travel with the fore part of the welding tip pointing straight into the line of travel and

slightly forward (Fig. 33). The *line of travel* means the direction of welding.

With the torch in the proper position, lower it until the point of the flame is about 1/16 in. from the plate at the right-hand end and about 1/2 in. from the side. Move the torch slowly in small semicircular motions, heating an area about 5/16 in. in diameter. The area under the torch will become a dull red color, then light red, and

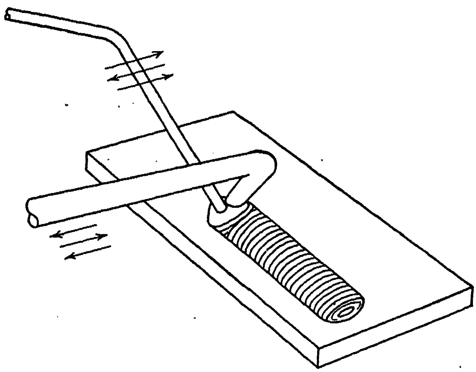


FIG. 33.—The end of the welding tip pointing ahead at a 45-deg. angle in the line of travel. The welding rod pointing into the puddle at a 45-deg. angle and straight in the line of travel.

finally white, and at this point the plate will begin to melt. The melted area is called the *puddle*.

After the puddle is formed, move the torch in straight back-and-forth movements at right angles to the line of travel. Carry the puddle across the plate to the other end (Fig. 34). Do not use a semicircular, or swinging, motion in carrying the puddle. Make the puddle about 3/8 in. wide.

As the puddle is carried forward, it will sink down into the plate, leaving a trough with smooth, even ripples (Fig. 34). The object of this lesson is to melt as deeply as possible into the plate without having the

bottom of the puddle drop out as it is carried across the plate. There will be a smooth, even weld on the bottom of the plate. The ripples, or lines in the weld, are caused by the torch movements.

In trying to establish the exact depth to which it is safe to penetrate without danger of the puddle falling through, you will no doubt burn a number of holes through the plate. However, upon close observation, the puddle may be seen to hesitate in its forward movement and apparently to quiver slightly just before it drops through. You have mastered the first step in welding when you recognize the point at which the puddle is about to drop through.

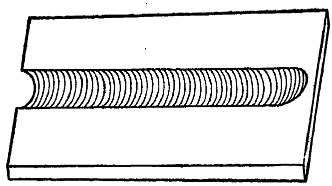


FIG. 34.—Melt as deeply as possible into the plate without the bottom of the puddle dropping through.

Pull the torch quickly away, and the puddle will begin to solidify. Then lower the torch into the puddle, pick up the weld, and continue carrying it toward the end of the plate.

Before leaving this plate you should make at least three consecutive welds, each about 4 in. in length, with full penetration and no holes.

LESSON 2

Making an Edge Weld

A simple weld may be made without a welding rod. It is possible to melt and flow two pieces of metal together without the use of a welding rod. The welding rod is often referred to as a *filler rod,* since it is used to fill in the cut or holes in the weld as it progresses and to build the weld deposit to the correct size.

Use two pieces of 18-gauge black iron, 2 in. in width and 4 in. in length. Place them on edge on the bench about 3 in. apart. Lean them together until the top edges come together evenly along the 4-in. side. The two pieces will form a tent shape (Fig. 35).

Using a No. 1 welding tip and 1 lb. pressure on the oxygen and acetylene regulators, adjust your goggles, light the torch and adjust it to a neutral flame, and tack the two plates together.

The tacks are made by playing the welding flame equally on both plates about 1/8 in. from the end. The

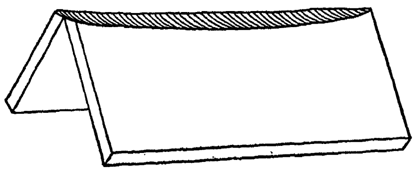


FIG. 35.—Melt and flow the edges of the plates together, securing as much penetration as possible.

point of the welding flame should be about 1/16 in. from the plates. The plates will melt and flow together under the flame. Make the tacks very small.

If you are right-handed, the weld will be made from right to left. Hold the welding hose in your left hand about 18 in. back from the torch, to prevent drag on the torch. Hold the torch as nearly level as possible, and at a right angle with the weld (Fig. 33). The welding flame must be straight in line with the line of travel and pointing ahead at about a 45-deg. angle.

Start the weld at the tack on the right-hand end. Move the torch in straight back-and-forth movements across the joint, covering an area about 3/8 in. wide. Do not use a swinging, or semicircular, motion. After the puddle is formed, proceed along the joint, fusing the

edges of the plates together as deeply as possible, without the puddle falling through, until the left-hand tack is reached.

The correct edge weld, or flange weld, is made by fusing the edges of the plates together to a depth of the thickness of the plates. In this lesson, however, the making of the actual weld is not the first consideration. While fusion is important, penetration is stressed, as in Lesson 1.

You must penetrate as deeply as possible into the plates without allowing the puddle to fall through. You will probably melt holes through the plates until you learn the exact depth at which the penetration must stop. You will notice, as in Lesson 1, that the puddle will cease its forward movement and quiver just before it falls through. Pull the torch out of the puddle quickly. Then, as the puddle begins to solidify, lower the torch and continue the weld.

Move the torch in straight back-and-forth movements across the joint. Do not use an up-and-down movement. The top of the weld should be very flat and about 3/8 in. wide, with the ripples, or lines in the weld, very fine and close together (Fig. 35). Every time the torch crosses the puddle, it leaves a ripple. Practice a uniform methodical movement of the torch.

You should make at least three consecutive plates with the characteristics described before proceeding to the next lesson.

Lesson 3

Making a Weld in the Flat Position, Using a Welding Rod

Lesson 3 is the most important of all the practice plates. In this lesson you learn to make a weld deposit,

using the correct technique for making a weld with the welding rod.

Master this lesson thoroughly before proceeding to another. The entire basic principle of welding, including torch and rod movement, width and depth of puddle, height and width of deposit, and uniformity of the weld, are learned from this plate. Every hour spent now will shorten the training period for more advanced plates.

Use 18-gauge black-iron scraps at least 2 by 4 in. in size. Place the practice plate flat on pieces of brick or metal so that it will be suspended at least 1 in. above the table (Fig. 32). Seat yourself close to the welding bench with enough of the welding hose resting across your lap to prevent drag on the torch. Adjust your goggles, and light and adjust the torch to a neutral flame. Hold the torch in the right hand, if right-handed, with the barrel of the welding torch as nearly at right angles to the plate as possible. The welding tip must be straight with the line of travel and pointing ahead at a 45-deg. angle.

Weld from right to left holding the $\frac{1}{16}$-in. mild-steel welding rod in the left hand. The rod must be held straight with the line of travel and pointing into the weld at about a 45-deg. angle (Fig. 33).

Since the $\frac{1}{16}$-in. welding rod is 36 in. in length and very limber, it is advisable to cut the rod in two and weld with one half at a time. Use the rod down to about 8 in.; then tack the short piece to the second half, and proceed with the weld.

Bend the welding rod at a 45-deg. angle about 6 in. from the end of the rod. This will allow you to hold the rod in line with the line of travel and to keep your hand out of the direct force of the welding flame. It also allows easier movement of the rod.

Heat an area $\frac{1}{4}$ in. in diameter near the right-hand end of the plate. Bring this area to a melting point; but, contrary to the practice with respect to the earlier plates, do not penetrate through the plate. The bottom of the plate should remain smooth and unbroken. As the plate melts and forms a puddle, hold the end of the rod close to the puddle so that it will heat at the same time. When the rod begins to melt, drop the end of the rod into the puddle and melt off enough metal to build the weld up to the correct size, about $\frac{5}{16}$ in. in width and $\frac{3}{32}$ in. in height.

When the desired size is obtained, use a crisscross motion of the torch and rod; that is, move the torch in a straight back-and-forth movement across the line of travel and move the rod in the same manner but in the opposite direction to that of the torch.

Using the crisscross motion, keep the weld a uniform size and carry it across the plate from right to left to the farthest edge of the plate. Do not leave a cutaway area at the end of the weld. Fill this edge by playing the torch on the rod, and deposit enough rod to fill the crater.

Gauging and controlling fusion and penetration are stressed in the lesson for this plate, since the weld is fused into the plate but does not penetrate it completely.

The advantage of the crisscross motion of the torch and rod lies in the fact that the torch preheats the exact area where the weld is to go and at the same time melts enough rod to build up the weld. In its crisscross movements across the line of travel the torch advances slightly with each motion. Each time the torch flame crosses the puddle, a new ripple is formed. The smoothness and regularity of the torch movements determine the appearance of the weld.

Never use a swinging, or semicircular motion, of the torch in making a weld. A motion of this type forms a large, loose puddle. Too much heat escapes into the plates, and the puddle is difficult to control in the vertical and overhead positions.

With the straight back-and-forth crisscross motion the torch stays just ahead of the weld and never retraces its path through the cooling area of the puddle. The deposited metal solidifies immediately behind the welding flame, making it easier to carry a puddle in the more difficult positions (Fig. 36). Since the welding rod is melting continuously under the welding flame, it must be fed into the puddle in order to keep the weld the correct size. The crisscross motion of the rod distributes the metal evenly across the face of the weld.

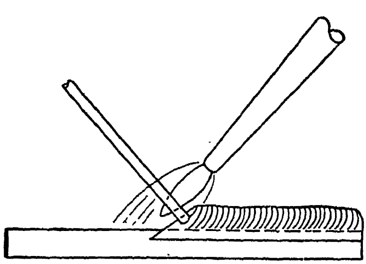


Fig. 36.—The welding rod rests in the center of the puddle. The torch is advanced slightly with each cross stroke.

Do not move the welding rod quite so widely as the torch flame. The edges of the weld are cooling rapidly, and if the rod is brought to the edge of the puddle the rod will "freeze."

Do not drag the welding rod ahead in the puddle. If the rod is dragged ahead during welding, the weld decreases in size and the welding flame digs too deeply into the plate. If the rod is carried too high in the puddle, the weld will become heavy and lumpy. Do not hold the rod above the weld and allow it to drip into the puddle.

If in making the weld you discover that the deposit is growing thin, allow the torch to play longer upon the rod.

This will increase the melting rate of the rod and decrease the heat in the plate. Laying the rod closer to the plate will increase the melting rate of the rod. Keeping the welding rod nearly vertical with the puddle will aid in decreasing the melting rate of the rod and increasing the heat of the plate. Resume the correct position as soon as the puddle becomes normal.

If the forward travel of the weld is too slow, the puddle will become overheated and the weld will be flat and

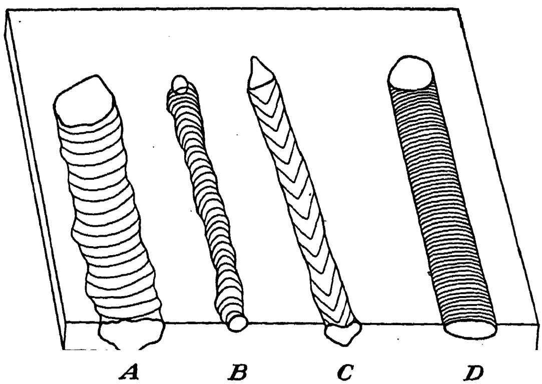


FIG. 37.—*A*, forward travel too slow; *B*, forward travel too fast; *C*, torch flame too hot; *D*, correctly made deposit.

uneven (Fig. 37). If the forward travel is too fast, the plate will receive insufficient heat and the deposit will be narrow and uneven, with thick edges, indicating poor fusion (Fig. 37). If the forward travel of the weld is too fast because the flame is too hot, the deposit will be flat and narrow, with V-shaped ripples (Fig. 37).

With the correct technique and procedure the weld deposit will be of even width, fairly flat across the top, and with the edges of the weld feathered into the plate. The ripples, or lines across the weld, will be at right angles to the line of travel and very close together (Fig. 37).

If the weld is stopped during its progress to change rods or to adjust the flame, special attention must be given to starting the weld again. Play the flame over the cooled puddle, and on the plate directly in front of the puddle, until it begins to melt and flow into the plate. Keep the end of the welding rod near the puddle so that it will melt at the same time. When the puddle melts, drop the end of the molten rod on the last high point of the weld puddle (Fig. 38). Melt a small portion of the rod at this point. Lift the rod out, and smooth the deposit with the regular crisscross motion of the torch. Drop the end of the rod into the center of the puddle, and proceed as before. It is necessary and important to practice stopping and starting the weld until it is impossible to discover from the appearance of the weld where the break occurs.

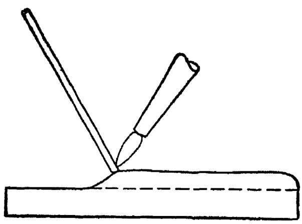


FIG. 38.—To restart, melt puddle and add rod at the last highest point.

During the welding process the flame may become blunted or crooked. This is due to sparks and oxides from the puddle adhering to the welding tip. Close the torch valves, and wipe the tip clean with a piece of canvas.

Do not scrub the tip on the bench or any other hard surface. The welding tips are easily damaged.

LESSON 4

Making a Weld in the Vertical Position

Select a piece of scrap 18-gauge black iron about 3 in. wide and 4 in. long to be used as a practice plate. Stand the plate on end in a vertical position. The weld is to

be made by progressing from the bottom of the plate to the top.

Tack together a jig (Fig. 39) of welding rods in order to hold the practice plate about shoulder level. This position of the plate will help you to keep the weld in view at all times.

Seat yourself at the welding bench slightly to the left of the practice plate, if you are right-handed. This will aid you in seeing the complete weld. Choice of welding position is important. Wherever possible, you must see the fore edge of the weld puddle and at the same time watch the finished surface of the weld as it is made.

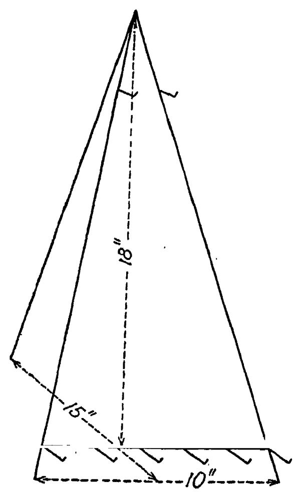


Fig. 39.—Jig to hold plates.

Use a No. 1 welding tip. Set the regulator pressures at 1 lb. Adjust your goggles. Light and adjust your torch to a neutral flame. Decrease the volume of flame on this plate; it is not practical to use as high a degree of heat in the vertical position as for the flat plate. However, if the torch pops continually, increase the length of the welding flame.

Hold the torch in the right hand between the thumb and first three fingers. In this position, the torch will be nearly at right angles to the forearm. The welding tip is straight in line with the line of travel and points ahead at a 60-deg. angle (Fig. 40*A* and *B*). It is advisable, on a vertical weld, to point the torch straighter into the puddle than for the flat weld. By doing this you avoid preheating too large an area in front of the puddle.

Hold the rod in the left hand. Bend about 6 in. of the rod at a 45-deg. angle so as to allow the rod to stay

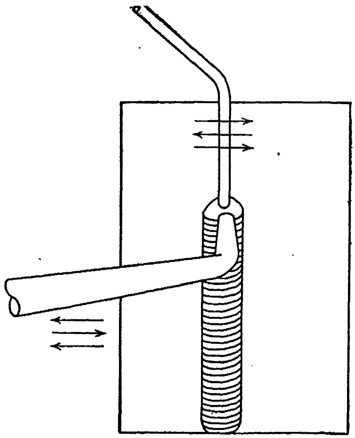


FIG. 40A.—Weld in the vertical position.

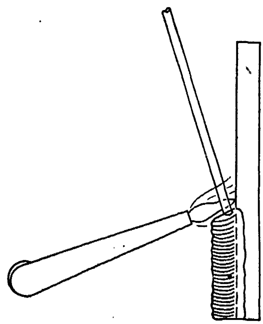
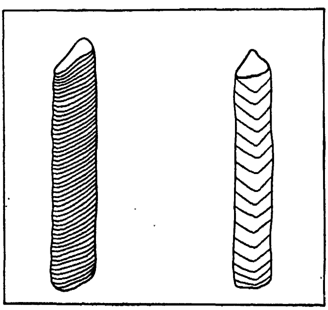


FIG. 40B.—Side view of vertical weld.

straight in line with the line of travel and yet keep the hand out of the direct heat of the welding flame. Incline the vertical portion of the rod away from the top of the plate so that it points into the puddle at a 60-deg. angle. Use the regular crisscross technique as for the flat plate.



A B

FIG. 41.—A, torch moved up and down across line of travel; B, forward travel too fast.

Begin the weld at the bottom of the plate, and carry it to the top. Finish the weld completely to the edge of the plate. Move the torch and rod exactly at right angles to the line of travel. Move the torch equally on both sides of the rod, or the weld deposit will be heavier on one side than the other. Do

not use a swinging, or semicircular, motion of the torch. The movement of the welding rod determines the width and uniformity of the weld. If the ripples on the finished weld are higher on one side (Fig. 41*A*), you have moved the torch up and down on the line of travel instead of straight across. If the ripples are V-shaped (Fig. 41*B*), the forward travel was too fast. If the forward travel is too slow, the puddle will grow large and run over and the plate will melt through. If the plate shows excessive heat in front of the weld, raise the torch and play it on the rod. Resume the regular position as soon as possible.

You should make at least five vertical beads with smooth even ripples, the edges well feathered into the plate and the surface fairly flat, before proceeding to another lesson.

LESSON 5

Making a Weld in the Horizontal Position

Place the practice plate, of 18-gauge black iron, in an upright position on the stand at eye level. The weld is to be made in a horizontal position, working from right to left. The horizontal weld must have the same appearance and quality as the flat and vertical welds.

A weld made in the horizontal position has a tendency to sag from the top, as the weld progresses, leaving a thin or an undercut edge along the top of the weld (Fig. 42*A* and *B*). There is a tendency for the weld metal to grow heavy along the bottom edge as the weld progresses.

Seat yourself comfortably at the bench with the hose drawn across your lap to prevent drag on the torch. Adjust your welding goggles. Light and adjust the torch to a neutral flame. Hold the torch in the right hand and the welding rod in the left. Bend the rod at a

45-deg. angle about 6 in. from the end. This bend keeps the hand out of the reflected heat of the torch.

To overcome the difficulties encountered in making a horizontal weld, the rod and torch will be held in a new position. Instead of being straight in line with the line of travel, the back end of the rod is raised about 30 deg. above the line of travel (Fig. 43). The back of the rod is also held away from the plate at about a 30-deg. angle. Move the butt of the welding torch forward so that the

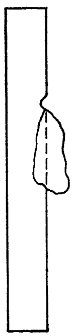


FIG. 42A.—Incorrectly made horizontal weld.

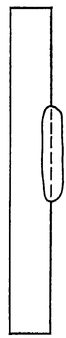


FIG. 42B.—Correctly made horizontal weld.

tip, instead of being straight in line with the line of travel, is pointing up at the weld at about a 30-deg. angle and ahead at a 45-deg. angle.

Although the position of the rod and torch is altered, the torch is still moved with the same crisscross motion directly at right angles to the line of travel. The torch is moved to the exact width of the desired puddle, but the welding rod, contrary to previous practice, moves only in the top half of the puddle (Fig. 43). Keeping the rod in the top half of the puddle ensures enough deposit to prevent undercutting along the upper edge of the weld. Moving the torch the full width of the puddle keeps

enough of the deposit drawn down to bring the weld to a uniform height and width (Fig. 42*B*).

You should make at least five horizontal beads with smooth even ripples, the edges well feathered into the

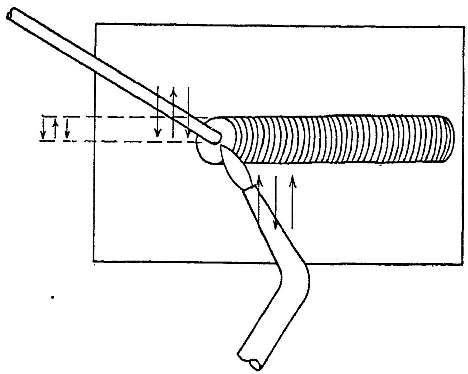


FIG. 43.—Position and movement of rod and torch in making a horizontal weld.

plate and the surface fairly flat, before proceeding to another lesson.

LESSON 6

Making a Flat Lap Weld

Select two pieces of scrap 18-gauge black iron, about 4 in. in length and 3 in. in width. Place one piece upon the bench and the other piece so that it covers half the first piece (Fig. 44).

Set the regulator pressures at 1 lb. Use a No. 1 welding tip and a 1/16 in. mild-steel welding rod. Adjust your goggles. Light and adjust the torch to a neutral flame. Tack-weld the four corners where the two plates touch (Fig. 44). Suspend the plates at least 1 in. above the bench, and place them so that you are looking directly

into the joint (Fig. 44). Do not reach over the top plate to make the weld.

The object of this lesson is to melt and flow the two plates together with the welding flame. The welding rod is used to build up the weld to the desired size.

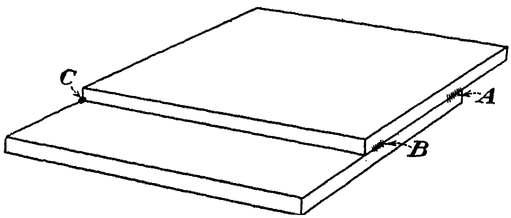


FIG. 44.—Flat lap weld. *A*, *B*, and *C* are tack welds.

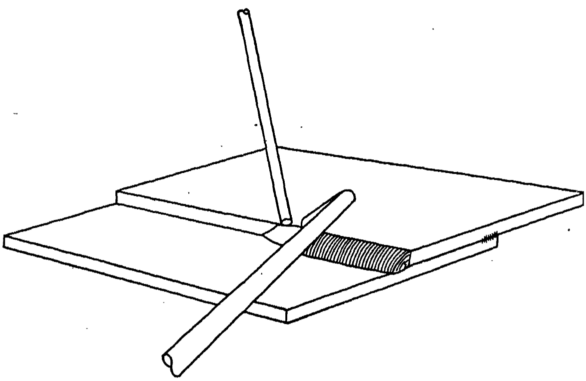


FIG. 45.—Flat lap weld. Note the two plates melting and flowing together ahead of the deposit.

Preheat the bottom, or flat, plate to a white heat for about 1½ in. along the joint, in order to bring the two plates simultaneously to the melting point. The flat surface of a plate requires more heat to reach the melting point than the edge of a plate.

Work from right to left, if right-handed. Keep the welding hose pulled across your lap to relieve drag on the

torch. Point the welding tip into the joint at a 45-deg. angle and ahead at a 30-deg. angle (Fig. 45). Keep the welding rod straight in the line of travel, pointing into the weld at a 45-deg. angle and resting on the extreme edge of the top plate.

In this lesson the welding rod is not moved from side to side or dragged ahead. It is fed into the puddle to fill in the low spots in the weld, to build the weld up to the correct size, and to prevent undercuts along the edge of the weld on the top plate. The motion of the torch is the straight back-and-forth movement.

The junction of the plates is the center of the weld. Half the weld is on the bottom plate, and half on the top plate. Keep the plates tightly together as the weld progresses, either by flattening them with a hammer or by an additional tack weld.

As the welding flame points forward, it melts the plates together ahead of the deposit. As it is moved from side to side across the line of travel, it melts the welding rod down into the puddle and distributes the melted metal evenly across the joint. Do not raise the point of the flame above the top edge of the joint, for this causes the top plate to melt away too rapidly, leaving a wide, ragged weld. The welding rod riding on the top edge of the plate acts as a buffer to protect the top plate from becoming too hot. As the welding rod melts, the end of the rod slides down into the puddle and must be lifted out and returned to its correct position on the top edge of the plate.

After the weld has progressed for about 2 in., you may notice that the top plate is melting more rapidly than the bottom plate. If so, stop welding, and preheat the bottom plate to a white heat before resuming the weld. Use the correct restarting technique (Fig. 38).

Be sure that the joint is melting and flowing ahead of the welding flame at all times. Otherwise, the top plate will melt and run down on the bottom plate, leaving an undercut along the top edge of the weld and a heavy rolled edge at the bottom edge of the weld (Fig. 46).

The correctly made weld is of unvarying width, about 5⁄16 in. It has no undercuts or rolled edges. The surface of the weld is slightly rounded, with smooth, tightly spaced ripples. The crown of the weld should be slightly higher than the top plate. The bottom of the plate should be smooth and unbroken.

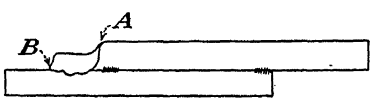


FIG. 46.—Poorly made lap weld. *A*, top plate undercut; *B*, heavy rolled edge.

In aircraft welding it is never advisable to start the weld at the edge and work toward the center. It is better to start the weld about 1 in. from the right-hand end and, by welding cross-handed, weld back to the right-hand edge, move to the end of the weld, and carry it across the plates. By carrying the heat to the outside edge, there is less possibility of the weld cracking. This is called *locking the weld* and should be done on all aluminum and stainless-steel welds.

LESSON 7

Making a Vertical Lap Weld

Line and tack two pieces of scrap 18-gauge black iron, in the form of a lap weld (Fig. 44). Stand the plates on end at about shoulder level. The joint must be facing you. In this position it is impossible to reach over the top plate to make the weld. The weld is to be made from the bottom of the joint, progressing to

the top edge of the joint. Do not leave a crater, or cutaway edge, at the finish of the weld.

Use a No. 1 welding tip, with 1 lb. pressure on each regulator. Adjust the torch to a neutral flame. Use a 1/16-in. mild-steel welding rod. Use the same welding technique on the vertical weld as for the flat lap weld. Move the torch in a crisscross motion directly at right angles to the line of travel so that the ripples will be exactly at right angles to the line of travel (Fig. 40*A*).

Do not allow the torch to point at a 90-deg. angle into the joint. This position of the torch melts the top plate and allows it to roll over the bottom plate, causing very poor fusion.

Feed the rod into the puddle, but not too far.

The appearance and quality of the vertical lap weld must be exactly like those of the flat lap.

Make at least three consecutive welds of the correct quality and appearance before proceeding to another lesson.

Lesson 8

Making a Flat Fillet Weld

Select two pieces of scrap 18-gauge plate, 4 in. long and 2 in. wide. Place one piece flat on the bench. Stand the other piece on edge in the center of the flat plate (Fig. 47). This is to be a fillet weld.

Set the regulator pressures at 1 lb. each. Use a No. 1 welding tip. Light and adjust the torch to a neutral flame. Use a 1/16-in. mild-steel welding rod. Tack the plates together at each end. Suspend the plates at least 1 in. above the bench. Work from the right-hand end of the joint to the left end, if you are right-handed.

Preheat the bottom, or flat, plate to a white heat for at least 1½ in. along the joint before beginning the weld. The flat plate requires much more heat than the edge plate in order to bring them to a melting point at the same time. When the flat plate begins to sweat, move back to the tack on the right-hand end and begin the weld.

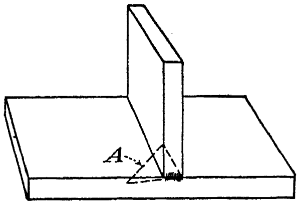


FIG. 47.—Flat fillet weld, horizontal position. Dotted lines indicate weld.

Point the welding tip into the weld at a 45-deg. angle from the joint and point ahead at about a 30-deg. angle (Fig. 48). The welding rod points into the puddle at a 45-deg. angle and leans away from the vertical plate at a 30-deg. angle (Fig. 48).

Build up a puddle, and then move forward slowly, using the crisscross motion of the welding torch and a

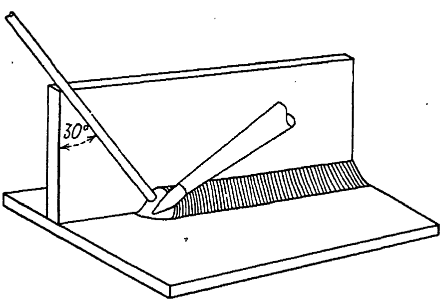


FIG. 48.—Flat fillet weld.

straight back-and-forth movement across the line of travel.

Do not raise the point of the welding flame quite so high on the vertical plate as you wish the weld to go. The reflected heat and the fact that the edge of a plate

melts easily will keep the vertical plate molten in the welding area. Play the torch about 60 per cent more on the bottom plate than on the vertical (Fig. 48).

The welding rod moves with a crisscross motion in an opposite direction from the welding torch. It moves, not the full width of the puddle, but in the top half. This technique aids in keeping the top edge of the weld full, preventing undercuts. The torch in its full travel keeps the base plates melting and moves enough deposit down on the flat plates to equalize the weld deposit. With the rod in the top half of the puddle the torch is able to bear directly into the joint and keep it melting and flowing ahead of the weld deposit as the weld is made.

The object of the weld is to melt and flow both plates together, penetrating to the bottom of the joint without breaking through either plate. The welding rod is added to fill in the joint and build the deposit up to the desired size.

The fillet weld requires a great deal of heat to keep the plates and weld flowing together. Unless care is exercised, the high degree of heat will cause the weld to penetrate completely through the plates. If insufficient heat is used, the weld will be a dark color, with a rough uneven surface, a rolled heavy bottom edge, and poor fusion along the top edge.

The correctly made weld is about 5/16 in. wide across the face, with a flat surface and with no undercuts along the top edges. The bottom edge of the weld is feathered into the bottom plate. The ripples in the weld are smooth and closely spaced. The weld has a shiny appearance, and the backs of the plates are unbroken. There is a white line at the back of the joint, indicating full penetration.

Test the fillet welds when you have become proficient (see Testing Weld Samples, page 230). Make at least three consecutive welds with the necessary qualifications before proceeding to another lesson.

Lesson 9

Making a Vertical Fillet Weld

Line and tack two pieces of scrap 18-gauge mild-steel plate together in the form of a fillet weld. Stand the plates on end at about shoulder level. Use a No. 1 welding tip. Set the regulator pressures to match the welding-tip size. Light and adjust the torch to a neutral flame. Use 1/16-in. mild-steel welding rod.

The weld is to be made by progressing from the bottom of the joint to the top. Finish the weld completely to the top of the plates.

Point the welding tip into the joint at a 45-deg. angle between the plates. Keep the rod straight with the line of travel and pointing into the weld at a 30-deg. angle.

Use the crisscross technique to make the weld. Play the welding flame more against the flat plate than against the edge plate in order to equalize the melting rate of the plates.

The welding rod rests in the puddle close to the fore edge of the puddle. The rod moves with a crisscross motion opposite the travel of the torch. Be sure the joint is melting and flowing ahead of the weld. Do not allow the welding flame to travel with a swinging, or semicircular, motion. This will cause the weld deposit to sag and have undercut edges along the weld.

Move the welding rod out to the edges of the weld on each cross stroke in order to flatten the weld and keep it

feathered into both edges. As the weld nears the top of the joint, the plates will become very hot. Play the torch more upon the welding rod when this condition occurs and move forward at a faster rate in order to keep the size of the weld uniform.

The appearance of the vertical fillet should be exactly like that of the flat fillet. Test the vertical fillet weld for penetration and soundness (see Testing Weld Samples, page 230).

Lesson 10

Making a Flat Butt Weld

Select two scrap pieces of 18-gauge black iron 4 in. long and 2 in. wide. Place them flat on the bench side by side. Space the plates apart the thickness of the metal to allow good penetration. It is not necessary to bevel plates under 1/8 in. in thickness in order to weld them. The spacing of the plates is very important because it determines the amount of penetration to be obtained. As the weld progresses, the plates will draw together. If they are spaced too closely, insufficient penetration is the result. The speed of the forward travel during welding determines the extent of the contracting action. Slow forward travel will pull the plates together much faster during welding than a higher rate of speed. Always be sure that the plates remain spaced until the weld reaches its end.

Set the regulator pressures at 1 lb. each. Use a No. 1 welding tip and a 1/16 in. mild-steel welding rod. Light and adjust the torch to a neutral flame. Tack-weld the joint on each end (Fig. 49). Suspend the plates at least 1 in. above the bench. Place the plates directly in front of you, with the joint extending from right to left. Make the weld from right to left, if right-handed.

Keep the welding tip straight with the line of travel and pointing ahead at about a 45-deg. angle. The welding rod is straight with the line of travel and pointing into the weld at a 45-deg. angle (Fig. 49).

Build up a puddle at the right-hand end of the joint, and move along the line of travel, using the crisscross motion of the rod and torch.

The object of this weld is to melt and fuse the plates together, obtaining full penetration. The welding rod is added to keep the weld to a uniform size.

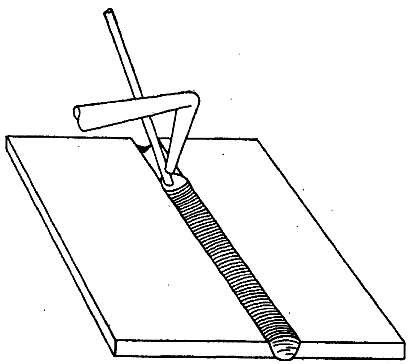


FIG. 49.—Flat butt weld.

The point of the welding flame extends past the welding rod and melts down the edges of the plate directly in front of the advancing weld. The melting metal flows back into the puddle, leaving an opening in the joint ahead of the weld at all times. This opening aids in securing good penetration and leaves an area in which to restart the weld if it is stopped during its progress.

The welding flame on its cross stroke never extends farther into the plates than the thickness of the plate (Fig. 50). The welding rod rests in the puddle and does not move quite so widely as the torch.

The penetration should extend through the plates and form a smooth, even bead along the bottom of the joint. The penetration bead should be rounded, with even ripples. If it is necessary to stop the weld during its progress, reheat the cooled puddle and the joint immediately ahead of the puddle.

FIG. 50.—Plates spaced to the thickness of the parent metal. Weld extends into the edges of the plate to the thickness of the metal.

When the puddle becomes fluid enough to flow ahead into the joint, fusing completely to the bottom of the penetration bead, lower the welding rod to the last highest point on the weld, deposit a small amount of metal, smooth with the torch, and lower the rod into the puddle. Move slowly down the face of the puddle with the rod and torch until the bottom edge of the penetration is reached, and then pull the torch and rod to the top of the puddle and resume the weld. You should be unable to discover from the appearance of the weld where the tie-in joint occurs.

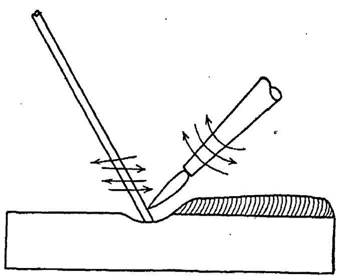


FIG. 51.—Whipping technique used in aircraft welding.

In aircraft procedure a variation of the crisscross motion may be used. Since the welding rod and plate are very light, they will melt easily. The torch may be moved in small, forward-swinging, up-and-down movements, alternately on the rod and plate (Fig. 51). No side motion is used. The rod is not moved sideways and is moved ahead or back only as required to keep the weld the correct size. The torch swings forward on the rod, melts a small amount of it, and then swings back into the plate and fuses the weld into the plate.

With practice, a very smooth uniform weld may be made with this procedure. However, if the student wishes to weld heavy material, this technique will not suffice. The welding rod used on heavy material is generally 3/16 or 1/4 in. If such a rod is left on the plate and not moved from side to side, there may be a cold spot directly ahead of the rod owing to the fact that the flame cannot penetrate to the plate to preheat it ahead of the weld.

With the whipping stroke the weld will probably be narrower and more rounded than the weld made with the crisscross stroke.

When the welds have attained their correct size and appearance, test for quality (see Testing Weld Samples, page 230). Make three consecutive butt welds with three samples from each weld passing the test, before you proceed to another lesson.

Lesson 11

Making a Vertical Butt Weld

Select two pieces of scrap 18-gauge black-iron pieces 4 in. long and 2 in. wide. Line and tack them together in the form of a butt weld. Use a No. 1 welding tip, with the regulator pressures set at 1 lb. each. Use a neutral flame and a 1/16-in. mild-steel welding rod. Tack-weld the plates together after spacing them at least the thickness of the plates.

Place the plates in a vertical position on the plate-holder. The weld is to be made by progressing from the bottom of the plates to the top. Finish the weld completely to the top edge of the plates.

Point the welding tip at a 30-deg. angle into the puddle. Keep the welding tip straight in line with the

line of travel. The welding rod is kept in line with the line of travel and points into the weld at about a 60-deg. angle (Fig. 52).

The crisscross welding procedure that was used on the flat butt weld is used on the vertical butt weld, except that the welding rod is held well toward the front edge of the puddle rather than in the center of the puddle as for the flat butt weld. This difference makes it possible to force the weld through the plate, securing full penetration. On a vertical butt weld the deposit has a tendency to flow back from the plates, leaving poor penetration on the back side of the joint.

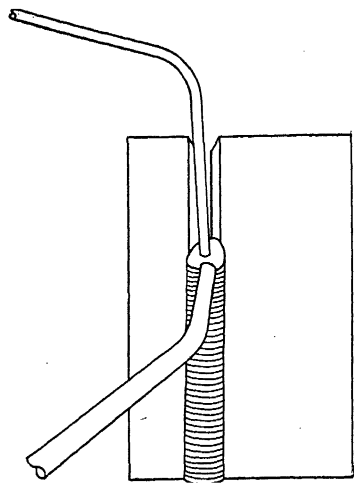


Fig. 52.—Vertical butt weld.

The weld should be of uniform width, about ¼ in. wide, and fairly flat across the top, with the edges well fused into the plates and the ripples smooth and closely spaced.

Make at least three consecutive vertical butt welds with the correct size and appearance. Test for strength, and be sure that three coupons from each weld stand the test before proceeding to another lesson.

Lesson 12

Making a Tube and Plate Weld

Use a 1-in. tube with a wall thickness of about 0.065 in. and a plate of 18-gauge black iron about 3 in. square.

If the tube is not available, use flat pieces and roll them over a 7/8-in. shaft to form a tube. Weld the seam as a butt weld.

Place the tube on end in the center of the plate. Use a No. 1 welding tip and 1 lb. pressure on each regulator. Light and adjust the torch to a neutral flame. Use a 1/16-in. mild-steel welding rod, and tack the tube to the plate in four places, using small tacks. Suspend the work at least 1 in. above the bench.

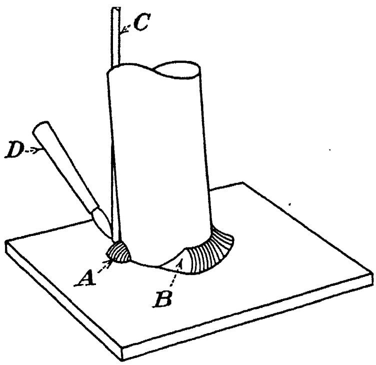


FIG. 53.—Tube and plate weld. *A*, starting end of weld; *B*, weld puddle; *C*, welding rod; *D*, welding tip.

Point the torch straight into the weld at a 45-deg. angle between the plates. The welding rod points into the weld at about a 30-deg. angle (Fig. 53). Begin welding at a point halfway between two tacks. Build up a puddle, and move forward using the crisscross technique as for the flat fillet weld (Fig. 48).

The tube and plate weld is a flat fillet weld. The only variation from the fillet made with straight plates is that the tube and plate weld is continually turning around a curved surface.

Keep the joint between the tube and plate melting and flowing ahead of the weld. The rod rests in the puddle

and moves mostly in the top half of the puddle. Care must be used to keep the weld a uniform width around the joint. When you reach a tack weld, pull the rod out of the puddle and melt the tack away and then drop the rod into the puddle and move forward.

In aircraft welding procedure, because of the composition of the metal, it is necessary to make a weld of this type by quarters (Fig. 54), thus relieving stress and

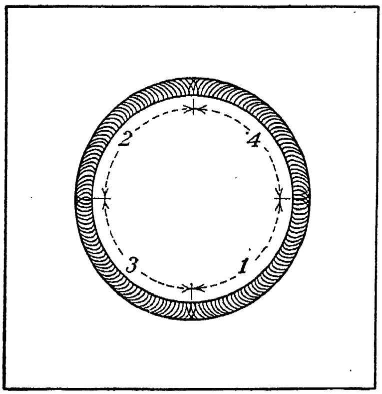


FIG. 54.—Top view of the tube and plate weld. Weld is made by quarters.

preventing the metal cracking in or near the weld. Fuse carefully into the end of the previous bead when you are tying the welds together to avoid cold shuts in the joints. Do not burn through the tube or plate in making this weld.

The weld should be about ¼ in. in width, with no undercuts along the top edge of the weld and no rolled edges along the bottom edge. The face of the weld should be flat, with smooth, closely spaced ripples.

Make at least three consecutive plates with these qualifications before proceeding to another lesson.

Lesson 13

Making a Rolling Tube Butt Weld

Select two pieces of steel tubing each about 2 in. in length and 1 in. in diameter and having a wall thickness of about 0.065 in. Place the tubes on the bench end to end. Be sure that they are in a straight line. Space the tubes about 3/32 in. apart. Use a 1/16-in. welding rod and a neutral flame. Tack the joint together in three places to keep it in line.

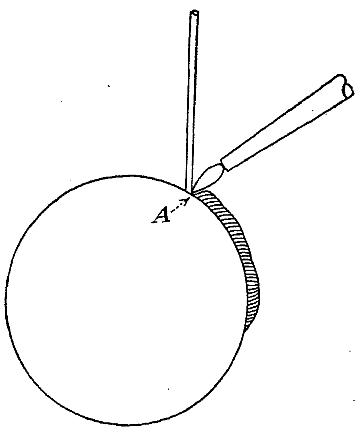


Fig. 55.—Top shoulder of pipe. The weld puddle is easily controlled at this point.

The rolling tube butt weld is made with the same crisscross welding technique as the flat butt weld made with plates. Keep the joint melting and flowing ahead of the weld, thus securing full penetration.

The easiest place on a tube weld to carry a puddle is at point *A* (Fig. 55). As the weld progresses, roll the pipe toward you to keep the puddle on or about point *A*. Keep the weld a uniform width around the joint. Be sure to melt away and fuse through the tack welds to ensure perfect penetration.

Use the restarting technique (Fig. 38) if it is necessary to stop the weld during its progress. It is well to make the beginning of the weld slightly narrower than the desired width. At the end of the weld you may fuse into the narrow section, leaving a weld of uniform height

and width. The whipping technique may be used on this weld (Fig. 51).

After the weld has cooled, saw the tubes apart close to the weld. Study the penetration bead carefully. There should be a uniform, unbroken bead around the weld on the inside of the tube.

The outside weld should be about 1/4 in. wide and fairly flat across the top, with no undercuts or rolled edges. The ripples should be smooth and closely spaced.

Make at least three tube welds with the correct qualifications before proceeding to another lesson.

Lesson 14

Making a Horizontal Tube Butt Weld

Use two pieces of steel tubing, each 2 in. in length and 1 in. in diameter and having a wall thickness of about 0.065 in. Use a No. 1 welding tip and a 1/16-in. welding rod. Use a neutral flame. Line and tack the tubes in the form of a butt weld, spacing them about 3/32 in. apart. Suspend the tubes on end about eye level, with the weld in a horizontal position.

Use the welding technique learned in Lesson 5. Be sure that the joint is melting and flowing ahead of the weld, and securing good penetration.

Keep the weld a uniform width around the joint. Fuse through the tack welds to ensure full penetration. Use the restarting technique if the weld is stopped during its progress. Be sure the weld is started slightly narrower than the desired width so that when the weld is brought to the starting point you may fuse into and around the end of the weld, thus obtaining perfect fusion and penetration without leaving a lump on the weld.

After the weld has cooled, saw the tube apart and inspect the penetration bead, which should be uniform and unbroken. The weld on the outside of the tube should be 1/4 in. wide, fairly flat across the face, and with no undercuts or rolled edges. The ripples should be smooth and closely spaced.

Make at least three horizontal tube welds, with good penetration and correct appearance, before proceeding to another lesson.

LESSON 15

Making an Overhead Tube Butt Weld

Select two pieces of steel tubing each 2 in. in length and 1 in. in diameter and having a wall thickness of about 0.065 in. Use a No. 1 welding tip, with corresponding pressures on the regulators. Use a 1/16-in. welding rod and neutral flame.

Place the tubes end to end in a straight line. Space them about 3/32 in. apart. Tack-weld the joint in three places, using small tacks. Suspend the pipe level with the eyes, with the weld in the same position as for the rolling butt weld. This weld is stationary and is made in two sections, progressing from the bottom of the joint to the top.

Since the weld metal will not sag or run until it is fluid enough to form a drop, there will be no difficulty in making the weld across the bottom of the joint if the usual crisscross method of welding is used.

The torch flame does not go back through the cooling area of the puddle but advances steadily with each cross stroke. The puddle cools as fast as it is deposited and shows no tendency to sag or drip.

Hold the torch in the right hand, if right-handed, and the welding rod in the left. Stand just to the left of the joint. Hold the torch under the joint until the welding tip is pointing straight with the line of travel and straight into the weld, at a point slightly past the center of the bottom of the tube. The rod is held straight with the line of travel, pointing into the weld at a 30-deg. angle.

Build up a puddle, and then move forward, using the crisscross technique. Do not use a semicircular motion of the torch or rod. Keep the welding rod resting in the fore edge of the puddle, not the center as for the flat butt weld.

Keep forcing the end of the melting rod up into the melting joint in order to secure full penetration and fusion. The crisscross motion of the welding rod spreads the weld deposit to the desired width and aids in preventing the puddle from sagging.

Keep the first ½ in. of the weld deposit narrow and flat but well fused and penetrated into the joint. As the puddle leaves the bottom and starts up the side of the joint, the most difficult part of the weld (*XY*, Fig. 56) is encountered. To overcome this difficulty, as the weld progresses up the pipe keep the welding tip straight with the line of travel and pointing straight into the weld and keep the welding rod straight with the line of travel and fairly flat against the tube (Fig. 56).

As the weld approaches the top of the tube, turn the welding flame straight into the weld and keep the welding rod perpendicular to the puddle. This prevents the weld flowing forward too rapidly and thus causing poor penetration in the joint.

Carry the weld puddle across the top of the tube slightly past center. Leave the last ⅜ in. of the weld

flat and narrow to allow the second half to join it without producing a heavy lump.

Assume the correct welding position on the other side of the overhead weld. Hold the welding torch so that it is straight with the line of travel and pointing straight into the weld, about ½ in. behind the starting end of the first bead.

Start the weld flowing, and deposit enough rod to bring the weld up to the desired size. Move slowly forward,

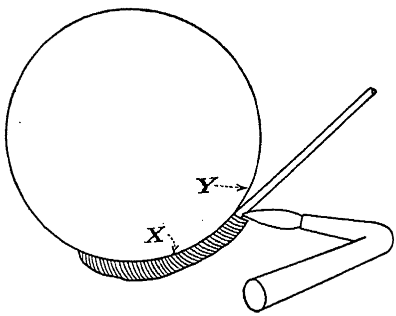


FIG. 56.—The area between points X and Y is the most difficult area in the pipe weld.

fusing well into the tubes and previously deposited weld, until the open joint is reached. Be sure that the edges of the joint are melting and flowing ahead of the weld, with the molten end of the welding rod held in the fore edge of the puddle and continually thrust up into the joint to obtain full penetration.

Adjust the position of the torch and rod as the weld advances, to compensate for the changing position of the weld puddle. Bring the weld up the tube to the top. Fuse well into the end of the previously deposited weld, carrying the puddle to the last highest point on the first half weld. Finish the weld smoothly at this point.

Saw the welded tubes into strips, and test for strength (see Testing Weld Samples, page 230). The surface

of the weld should be ¼ in. wide, of uniform width, fairly flat across the top, and with smooth, closely spaced ripples. There should be no indication of where the welds were stopped and started, other than the shape of the ripples at the bottom of the weld.

Make at least three consecutive overhead tube welds, with two coupons from each meeting the requirements, before proceeding to another lesson.

LESSON 16

Making a Tube T Weld

Use two pieces of steel tubing 2 in. in length, 1 in. in diameter, and about 0.065 in. in wall thickness. Hold

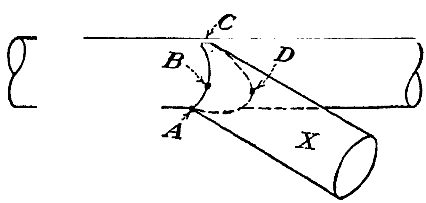


FIG. 57.—Rolling T weld.

the end of one tube against the corner of the grinding wheel, and grind it to fit closely against the side of the other tube (Fig. 57). This is called a *saddle weld* or *T weld.*

Use a No. 1 welding tip and a $\frac{1}{16}$-in. mild-steel welding rod. Tack the joint in four places, *A*, *B*, *C*, *D* (Fig. 57), to keep the tubes in line.

In this lesson the joint may be turned in any position to keep the weld puddle in an easy position to weld. To obtain the full benefits of this practice, turn the vertical tube *X* in a flat position and begin to weld at point *B* (Fig. 57). Notice that the weld in this area is a vertical

fillet weld and must be made with the vertical-fillet-weld technique. As the puddle nears the area at point *C*, the joint becomes a flat lap weld. Weld this section with the flat-lap-weld technique. You will notice that, in order to keep the weld a uniform width, more welding rod must be deposited in the fillet-weld section than in the lap-weld section. Carry the weld slightly past the center of the joint at point *C*.

Start the weld narrow and flat at point *B*, and finish with a narrow flat weld at point *C* (Fig. 57).

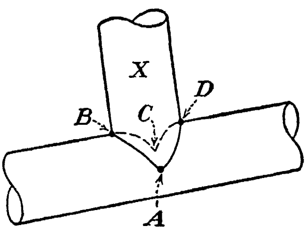


Fig. 58.—Vertical T weld.

In the second quarter of the weld, point *D* to point *C* (Fig. 57), observe the same welding technique as for the section *B* to *C*. Finish the weld at point *C* smoothly, without leaving a hollow or a heavy lump.

Turn the joint over, and weld from *B* to *A* and then from *D* to *A*. Use the correct restarting technique at points *B* and *D*. Finish carefully at point *A* to avoid a heavy lump or sunken area.

Practice making this weld with both tubes stationary and the tube *X* in a vertical position. Use a No. 1 welding tip and a 1/16-in. welding rod. Tack the joint in four places, *A*, *B*, *C*, *D* (Fig. 58), making small tacks. Begin the weld at a point about 1/4 in. past point *A* between *A* and *D*, and carry the puddle to point *B*.

With the tubes in this position the area around point *A* is a lap weld in a horizontal plane. Adjust the torch and rod in the positions recommended and practiced in Lessons 5 and 14. Weld the joint as a lap weld, keeping the center of the joint in the center of the weld. This means that the weld should be evenly divided, with

equal amounts on the flat and vertical tubes. Next weld the section from *C* to *D*, observing the same welding techniques as in the section from *A* to *B*.

The next sections to be welded are from *A* to *D* and from *C* to *B*. These involve holding the torch barrel and rod in a different position (Fig. 59). The welding tip must be in the correct position on any weld, regardless of where the welding barrel is held. Bend the welding rod so that it fits around the tube, is straight

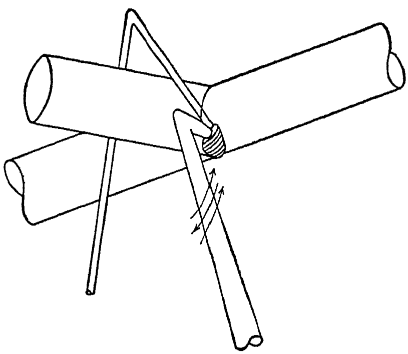


FIG. 59.—Keep the weld puddle level.

with the line of travel, and is pointing into the weld at a 30-deg. angle. Hold the welding tip at a 45-deg. angle between the tubes and pointing ahead at a 30-deg. angle (Fig. 59).

If the weld puddle shows a tendency to roll and grow heavy along the bottom edge, use the crisscross motion of the torch and rod, but remember to move the torch farther forward on the downstroke than on the upstroke (Fig. 59). This leads the bottom edge of the puddle forward and keeps the puddle level with the bottom edges of the plate and feathered into the bottom plate, preventing a rolled edge. The welding rod is kept in the

top half of the puddle as for the horizontal weld and the flat fillet weld. This, as you have learned, keeps the weld full along the top edge next to the vertical tube *X* and prevents undercutting.

Another method of welding the T weld is to turn the tube *X* in a vertical position and weld from point *D*, around through point *A*, to point *B* (Fig. 60). As the weld progresses down the side of the tube from point *D*, it leaves the fillet weld and becomes a horizontal lap weld from point *S*, through *A*, to *T*. This is a difficult area to weld. Practice here must be thorough until the puddle is under control.

As the weld approaches point *A* and starts toward point *B*, through point *T*, the torch must be rolled, or turned in the hand, to keep the welding tip straight with the line of travel, at a 45-deg. angle between the tubes, and pointing ahead at a 30-deg. angle (Fig. 59).

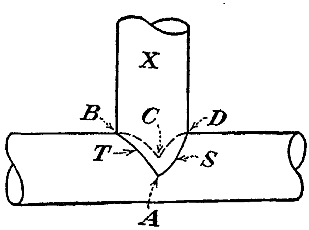


Fig. 60.—Vertical T weld.

Use the same procedure to weld from *B*, through *C*, to finish at *D*.

If you remember that, regardless of the position of the joint to be welded, the torch and rod must be held and moved so that the actual weld puddle is kept level, you will have no difficulty in welding joints in odd positions.

Keep the weld a uniform width, about ¼ in., around the joint. The weld must be flat across the face, with smooth, closely spaced ripples. Avoid undercuts or rolled edges.

Do not allow the weld to break through the tubes. Make at least three consecutive welds of the different

tube joints with the necessary qualifications before proceeding to another lesson.

LESSON 17

Making a Tube Cluster Weld

Use three pieces of steel tubing, each 4 in. long, and one piece of steel tubing, 6 in. in length and 1 in. in diameter, with a wall thickness of about 0.065 in.

Grind tube *X* to fit tube *Y*, and tack-weld them together. Grind and fit tubes *W* and *Z* to fit at a 45-deg.

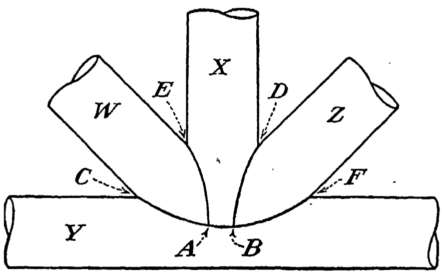


FIG. 61.—Tube cluster weld.

angle between tubes *X* and *Y* (Fig. 61). The fit of the tubes should be very close to facilitate welding. Space the tubes 1/16 in. apart. Tack-weld tubes *W* and *Z* to tubes *X* and *Y* with very small tacks.

Begin the weld at point *A*, at the lower edge of the tubes *X* and *W* (Fig. 61), and carry the weld to and slightly past point *E*. The area around point *E* requires a great deal of heat and welding rod to bring the weld to a uniform size. Secure full penetration and fusion between the tubes at this point without burning through the tubes, or leaving undercuts or rolled edges. The rolled edges will occur if too little heat is used.

Next, weld from point *B* to point *D*, observing the precautions recommended for the area from point *A* to

point E. Weld from point F to point C, fusing well into points A and B and leaving no undercut or rolled edges.

As the weld approaches a tack or a previously deposited weld, pause and preheat thoroughly before bringing the weld across. Points F and C require special attention to heat to obtain full fusion and penetration.

Turn the tube cluster around, and weld the corresponding sections as in the areas from A to E, B to D, and F to C (Fig. 61).

The welds should be about ¼ in. wide and the surface fairly flat, with smooth, closely spaced ripples. The edges of the weld should not be undercut or heavy.

Make at least three consecutive clusters, with the correct appearance and quality, before proceeding to another lesson.

Lesson 18

Making a Tube Angle Weld

Use a piece of 1 in. steel tubing, 6 in. long, with a wall thickness of about 0.065 in. Using a hack saw, cut the tube in two at a 45-deg. angle (Fig. 62A). Fit the two pieces together to form an angle (Fig. 62B).

All angle welds, when cooling, have a tendency to shrink to the throat. Space the joint slightly wider in the throat to allow for the normal contraction so that the joint will be straight after cooling. Since the speed of welding affects the rate of contraction, experience must teach you the needed allowance. The spacing allows better penetration into the throat of the weld.

The order of tack welding aids in controlling distortion. After the tubes are lined, space them at least 1⁄16 in. apart and slightly more at the throat. Tack-weld the point of the angle first; then tack-weld in the

center of the top side of the weld, turn the pieces over, and tack-weld on the opposite side (Fig. 62). Tack-weld the throat. Use very small tack welds throughout.

Begin the weld at point *B* (Fig. 62). Weld from point *B*, through point *A*, to point *C*. Finish by welding from point *C*, through point *D*, to finish at point *B*.

There are two areas in the angle weld requiring special consideration, the point and the throat (Fig. 62). The side of the joint is a butt weld and requires the usual butt-weld technique. The throat of the angle weld

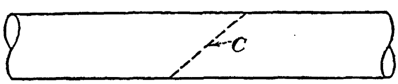


FIG. 62*A*.—Dotted line indicates saw cut.

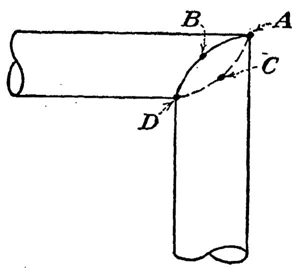


FIG. 62*B*.—Turn one tube half over and line as an angle weld. *A*, *B*, *C*, *D* are tack welds.

requires a great deal of heat and rod to fill in and obtain good fusion and penetration and to keep the weld to a uniform size.

As the weld nears the point, it becomes an edge, or a flange, weld and requires the proper technique for an edge weld. The weld in the area of the point will become high and narrow if precautions are not used to offset the condition.

The weld should be about ¼ in. wide, fairly flat across the face, well feathered in at the edges, and with smooth, closely spaced ripples.

Hack-saw the tubes apart beside the weld, and inspect. The penetration bead should be well through the joint, with no breaks indicating stops and starts. The penetration bead must be of uniform width.

Make at least three angle welds with the necessary qualifications before proceeding to another lesson.

CHAPTER V

AIRCRAFT WELDING, FINAL TEST PLATES OF ARMY AND NAVY *A* TEST

Lesson 19

Making a Flat Butt Weld

The previous lessons have been applicable to aircraft welding as well as to general welding; in fact, the butt welds and tube weld are qualifying test plates for a class *B* aircraft welder. The following three lessons deal with the final test plates for a certified *A* aircraft welder. They contain much practical welding knowledge, which must be mastered for the construction of such plates.

In making these plates a much smaller welding tip and rod will be used than for the same thickness of metal in general construction work. Using the small tip and rod necessitates close observance of the rules for preheating, fusion, penetration, and control of the weld puddle. Details of welding that are ordinarily overlooked when the larger tip and rod are used must be watched.

Select two pieces of ¼-in. mild-steel plate, each 6 in. long and 3 in. wide. Bevel one edge on each plate to a 60-deg. angle. Place the plates flat on the bench with the bevels facing each other. Space the plates $\frac{3}{16}$ in. apart.

Use a No. 3 welding tip and a $\frac{3}{32}$-in. copper-coated welding rod. Set the regulator pressures at 4 lb. each.

Check the flame frequently to ensure a neutral flame at all times. Tack the plates together at each end, using small tacks. Suspend the plates at least 1 in. above the table. Make the weld from right to left, if right-handed. Keep the welding tip straight with the line of travel and pointing into the weld at a 30-deg. angle. The angle of the welding tip aids in holding the weld puddle back while full fusion and penetration are secured. Hold the welding rod straight with the line of travel and pointed into the puddle at a 30-deg. angle.

Preheat the beveled edges of the plates, for about 2 in. along the line of travel, until they become white-hot and begin to sweat. Do not allow the welding flame to play over the area outside the joint to be welded, for this causes unnecessary distortion of the plates.

Hold the welding flame on the right-hand end of the joint. When the bevels are melting and flowing, add welding rod and advance along the joint, welding the bottom edges of the joint together and securing full penetration and fusion. Carry the sealing bead forward for 1 in. Then move back to the beginning, build up the weld to the required size, and carry the weld forward, fusing well into the sealing bead and faces of the bevels to within ¼ in. of the end of the sealing bead. Lift the rod out of the puddle, and use the restarting technique to pick up the sealing bead, carrying it forward for 1 in. Drop back, pick up the finishing bead, and carry it forward. Continue this alternating procedure to the end of the plates.

Keep the bevels of the plates preheated for 2 in. ahead of the puddle to avoid cold laps or poor fusion.

This method keeps the weld puddle from rolling forward and bridging over the bottom edges of the joint, causing poor penetration. If the left end of the plates

were raised until the weld was made in an uphill position, the weld would be made in one pass, for the melted metal would flow back from the puddle. Make the weld in a flat position, for thus more skill is required to control the puddle.

Use the crisscross motion of the rod and torch to keep the heat concentrated in the weld puddle and joint and to keep the finished weld to the correct size. Be sure that the faces of the bevels and the first pass are melting and flowing directly ahead of the weld puddle.

It may be necessary during the crisscross stroke to move the torch ahead in the line of travel to aid in the preheating of the area directly in front of the weld puddle in order to obtain perfect fusion and penetration. The side motion of the welding rod distributes the weld metal evenly across the joint and fills in the edges of the weld, thus preventing undercuts.

The weld should be $\frac{1}{8}$ in. wider than the top edges of the bevels and not over $\frac{1}{8}$ in. higher than the plates. The weld should be fairly flat across the face, with the edges feathered well into the plates and the ripples very close together. The penetration bead should be rounded and should protrude through the plates about $\frac{3}{32}$ in.

Make at least three consecutive plates with the correct appearance qualifications, and be sure that four coupons from each weld pass the tests before proceeding to another lesson (see Testing Weld Samples, page 229).

Lesson 20

Making a Cross Weld

Use two pieces of $\frac{1}{4}$-in. mild-steel plate, 3 in. long and 2 in. wide, and one piece 6 in. long and 2 in. wide.

Place the plates on edge, with the two short pieces against the center of the longer piece to form a cross (Fig. 63).

The ends of the plates must be ground square for this test; no bevels are used. Space the pieces 3/16 in. apart. Use a No. 3 welding tip and a 3/32-in. copper-coated mild-steel welding rod. Adjust the torch to a neutral flame, and tack-weld lightly on the top edges of the joint. Turn the cross over, and tack-weld the edges.

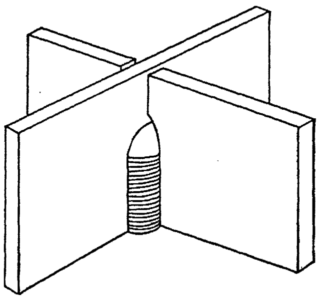


FIG. 63.—Cross weld. The weld puddle is long and sloping.

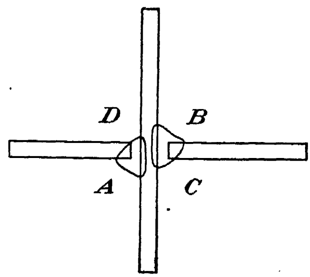


FIG. 64.—Top view of cross weld. Letters indicate order of deposit.

Suspend the joint at least 1 in. above the table, with the welds in a vertical position.

The welds are to be made in the sequence shown in Fig. 64. In welds *A* and *B*, full penetration is secured through the joint. This is important, for it will be impossible to secure good fusion and penetration from sides *C* and *D* if the penetration does not extend through the joints from sides *A* and *B*. The weld must penetrate or fuse in the center plate to at least 25 per cent of its thickness, or 1/16 in.

Owing to the nature of the joints to be welded, heat plays a very important part. Preheat the cross to a red heat before beginning the weld at point *A* (Fig. 64).

Point the welding flame against the center plate rather than the edge plate, for the former has a larger surface to be heated. Add rod to form the basis of a puddle, and continue heating the plates until the center plate begins to sweat for at least 5/8 in. ahead on the line of travel and through the joint to the back side of the edge plate. Allow the end of the edge plate to melt and flow down into the puddle until the back side has been reached. Drop the rod into the puddle, and make a sealing bead, or penetration bead, about 5/8 in. in length and completely through the joint. Pause and preheat the plate again until the heat is built up, paying particular attention to the back side of the weld just started.

Begin the weld at the bottom of the joint, and carry the puddle ahead for 1/2 in., stopping just behind the edge of the penetration bead. Lift the rod out of the puddle, and preheat as before. When the plates are hot and the area to be welded is beginning to sweat, pick up the end of the penetration bead and advance it for 3/4 in. The speed of welding will be greatly facilitated if another torch is used, by another welder or a mechanical device, to keep the plates and joint hot during welding.

Drop back to the finish weld, and heat it until both plates and the penetration bead are beginning to melt and flow. Add the welding rod; and, using the criss-cross technique, advance the weld to within 1/8 in. of the end of the penetration bead.

Keep the puddle long and sloping (Fig. 63) in order to obtain full fusion into the joint and to prevent the *black spot* occurring. This condition appears in the weld if the heat in the back of the joint is allowed to drop or if the back of the puddle is built up until the puddle is

level and a crater is thus formed in its fore edge. If an imperfectly fused globule of metal falls upon the plates just above the puddle, a crater will also form. It is impossible to reheat the bottom of such craters to a melting point. Pointing the welding flame directly into the crater heats its upper edges, but a cold dark spot appears at its bottom. This is the black spot. At its appearance, stop at once and preheat the plates until they become a bright red. Hold the flame at the back edge of the cooled puddle until it begins to flow. Move forward slowly, allowing the melting metal to flow back from the joint into the puddle until the dark area is reached and washed away. Hold the end of the welding rod near the flame, and keep it molten. As the black spot washes away, deposit the rod and see that it is well fused, adding small amounts until the low area is built up and the puddle is again normal. If the black spot continues to grow, start back on the weld below the puddle and melt away enough metal to remove the black spot completely.

Carry the finish weld completely to the top edge of the plates. As soon as the weld on side *A* is completed, make the weld on side *B*. Use the same preheating precautions and obtain full penetration as far through the joint as possible, as for side *A*. When side *B* is completed, weld side *C*.

The first step in welding side *C* (Fig. 64) is to melt away the back of the penetration bead from side *B* until all oxides and impurities are removed and clean, smooth metal is visible, with no pockets or thin gold lines indicating poor fusion.

Keep the plates and finished welds thoroughly preheated, and weld side *C* as a fillet weld. Be sure that the metal is melting and flowing ahead of the puddle as

the weld progresses, and keep the puddle long and sloping as for the previous weld. If a black spot occurs, remove it by the described method with reference to sides *A* and *B*. *Never attempt to cover up or weld over a black spot.*

When side *C* is completed to the top of the plates, weld side *D* in the same manner.

The finished weld should be 5/8 in. wide across the top, the edges being well feathered into the plates with no undercuts or rolled edges. The surfaces of the welds should be slightly rounding, with the ripples smooth and close together.

The welder may test his own work by using a No. 6 welding tip and, starting at the top of each weld, washing the deposit away from the plates. The four welds should be washed out and carefully inspected. If they are correctly made, the melting metal will be clean and shiny, with no breaks to mar its flow. It will be impossible to discover the joint between the sides of the weld and the plates. If any black spots were covered up in the weld, the melting metal will flow away from them, leaving the craters. If improper fusion was obtained along the side of the weld or in the restarting of the weld, a thin gold line will indicate the point where this occurred.

Make at least two cross welds, of good appearance, that can pass the flame test, before proceeding to another lesson.

Lesson 21

Making a Single Tube and Plate Weld and a Cluster Tube and Plate Weld

For the single tube and plate weld select a piece of 1/4 in. mild-steel plate, 4 in. square, and one piece of

0.065 in. tubing, about 1 in. in diameter and 5 in. in length. Saw a slot in the tube 3 in. long and 3/8 in. wide. Slip the tube over the 1/4 in. plate (Fig. 65). Slip a 1/16 in. welding rod under the tube to space it from the plate and to facilitate welding.

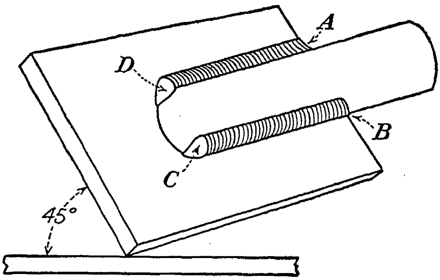


Fig. 65.—Tube and plate weld.

Using a No. 3 welding tip and a 3/32-in. copper-coated mild-steel rod, preheat the entire plate to a bright red before beginning to weld. Keep the tube as cool as possible. Tack the weld at points *A*, *B*, *C*, *D* (Fig. 65). Use small tacks.

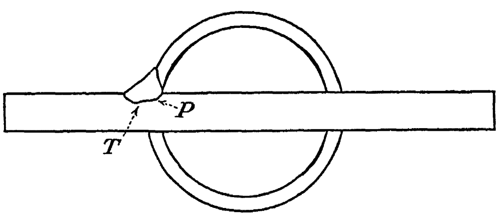


Fig. 66.—End view of tube and plate weld.

To aid in controlling the weld puddle and in securing full penetration, turn the tube and plate up on the side, with the plate at a 45-deg. angle from the bench (Fig. 65). The weld must be fused into the plate and tube without leaving an undercut or rolled edge. The penetration must be between 25 and 40 per cent at point *T* (Fig. 66)

and a minimum of 20 per cent at point P, directly under the inside edge of the tube. The inside of the tube must be unbroken, although the penetration must reach completely to the inside of the bottom edge of the tube.

Make the first weld from A to D (Fig. 65) with the plate tipped. The junction between the tube and plate is plainly visible. Hold the torch so that the welding tip is straight with the line of travel and pointing into the joint at a 30-deg. angle in order that the weld may be driven under the tube. Hold the welding rod against the edge of the tube, feeding it into the puddle from the tube side. The welding rod protects the tube from melting too rapidly.

Preheat the plate after tack welding. If possible, use another torch to keep the plate hot during welding. Make the weld from A to D (Fig. 65). Build up a small puddle at point A. Move the torch forward for ½ in., melting deeply into the plate just under the tube. As the torch moves forward, the outside edge of the tube melts back until the inside edge is exposed. Do not break through the tube, but move back to the beginning and, dropping the rod into the puddle, advance along the line of travel, using the crisscross stroke. The side motion of the welding rod keeps the deposit full along the top edge of the weld on the tube side, preventing undercuts. The rod aids in feathering the weld into the plate, thus preventing undercuts or overlap. Keep the plate preheated at all times. Keep the tube melting back and the plate melting and flowing ahead of the advancing weld to ensure perfect fusion and penetration. It may be necessary at intervals to lift the rod from the puddle or hold it tightly against the tube, allowing the torch flame to play on the area ahead of the weld to bring it to the welding heat.

Carry the weld to point D (Fig. 65). Tilt the plates in the other direction and weld from B to C. The same welding technique is used on this side as from A to D. More care must be exercised on the side from B to C to prevent burning through the tube. Keeping the welding rod close to the tube and carrying the weld slightly ahead on the plate side will aid in equalizing the melting rate of the tube and the plate. When the weld is completed to point C, turn the plate over, remove the scale, and weld both sides of the tube to the plate. This side will require more welding heat, for the addition of weld metal has increased the size of the plate.

Practice this plate until you can make two consecutive welds each weld $\frac{3}{8}$ in. wide, having the edges feathered into the tube and plate, the ripples smooth and closely spaced, and the tops fairly flat, with no undercuts or overlaps.

For the cluster tube and plate weld use three 1 by 0.065 in. tubes about 6 in. long and a piece of $\frac{1}{4}$ in. plate 3 by 6 in.

Slot one tube about 2 in. deep and $\frac{3}{8}$ in. wide. Slip this slot over the plate (Fig. 67). Heat the end of the tube and round the end down to the plate. Slot the other tubes $1\frac{5}{8}$ in. deep, and grind at a 45-deg. angle to fit the center tube (Fig. 67). Leave $\frac{1}{16}$ in. clearance on all joints.

Preheat the plate to a bright red, and weld the center tube to the plate according to previous instructions. Slip the two angle tubes over the corners of the plate until they fit against the center tube (Fig. 67). Tack-weld them in position. Weld from F to H and from E to G. Turn the cluster over, and make the corresponding welds. Turn the plate in any position to facilitate welding. Be sure that the tubes are well fused and that

penetration is good, without breaking through the inner surface of the tubes.

Weld from point L, through point H, to joint J (Fig. 67). Be sure when crossing the ends of the previous welds that perfect fusion is obtained, with no undercuts. Weld from K, to J, through G. Turn the cluster over, remove the scale, preheat, and make the corresponding weld on that side. Watch the weld puddle closely to

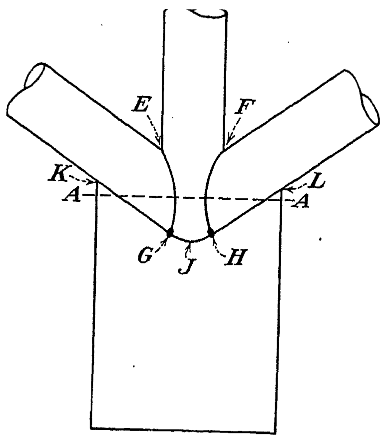


FIG. 67.—Cluster tube and plate weld.

be certain that it is penetrating into the plate and tube to the correct distance (Fig. 66).

After the weld has cooled, saw the cluster apart at points AA. File the saw marks from the plate, and use emery cloth to remove the file marks and to polish the cut.

Dip the polished end into a saturated solution of ammonium persulphate. This process is called *etching*. The weld deposit so treated will show clearly against the parent metal, and lack of fusion or penetration is easily seen (Fig. 68).

Study the imperfections in the weld carefully. Then make another weld, striving to correct any errors.

Figure 68 shows an end view of etched welds in a cluster tube and plate weld. Points 1, 4, 5, 8, and 9 are satisfactory. Good fusion and full penetration have been obtained, without marring the inside of the tube. Points 7 and 11 are good except that the penetration extends

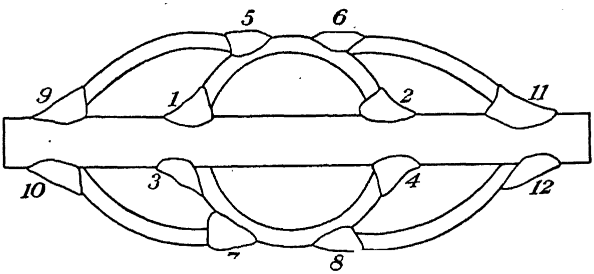


FIG. 68.—Etched section of tube cluster and plate weld.

through the tubes. Point 2 is too flat on the plate, and the penetration extends too deeply into the tube. Point 3 lacks sufficient penetration into the tube. Point 10 lacks good penetration not only into the tube but also into the plate. Point 12 is well penetrated into the plate but is not penetrated deeply enough into the tube.

Make at least two consecutive cluster welds, without undercuts or overlaps and with full penetration and fusion, before proceeding to another lesson.

CHAPTER VI

PIPE WELDING, FOREHAND AND LINDEWELD TECHNIQUE

LESSON 22

Making a Rolling Pipe Butt Weld

Forehand Method.—Use two pieces of 8-in. standard line pipe, each about 12 in. in length. Bevel one end on each pipe to a 45-deg. angle, using a roundabout to mark the pipe so that a straight cut may be made around the pipe (Fig. 69).

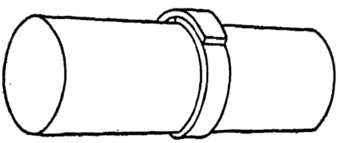


FIG. 69.—Roundabout in position on pipe.

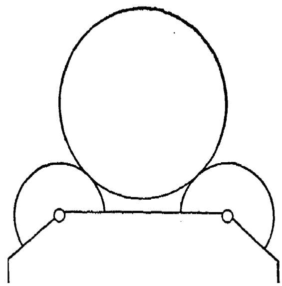


FIG. 70.—Pipe on rollers.

Place the pieces of pipe straight in line, with the beveled ends together. Space the joint about 3⁄16 in. between the bottom edges of the bevels. Use a No. 6 welding tip, with the welding pressure set at 6 lb. on each regulator. Use a neutral flame and a ¼-in. high-test welding rod.

Tack-weld the joint on the top center, then on each side at the centers. Roll the joint over, and tack the last quarter. The tacked joint should be on rollers or blocks to allow it to roll easily as the weld progresses (Fig. 70).

Keep the welding tip straight with the line of travel and pointing ahead at a 45-deg. angle. The welding rod must be straight with the line of travel and pointing into the weld at a 45-deg. angle.

Begin the weld halfway between two tacks, and keep the pipe turning as the weld progresses, holding the weld at point *A*. This is the easiest position in which to carry a puddle (Fig. 71).

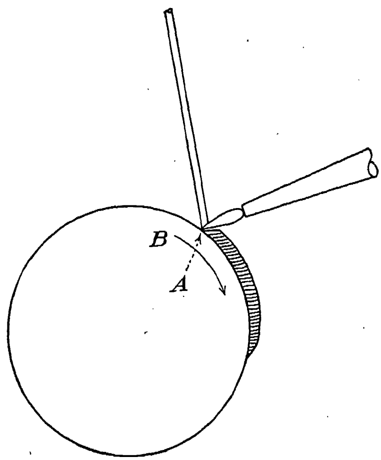


FIG. 71.—Rolling pipe weld. *B* indicates direction of pipe movement.

Heat the bevels to a sweating heat for 2 in. along the joint ahead of the starting point. Move back to the starting point, and begin melting the bevels. Add welding rod, being sure that it penetrates through the joint, and build up the puddle. Move forward, using the crisscross technique, for about 1½ in., welding the two bottom edges of the joint together and securing full penetration. Move back to the starting point, build up the weld puddle to the desired size, and move forward, making the finish weld.

From time to time, lift the welding rod out of the puddle and allow the flame to play on the face of the bevels, on the penetration bead, and ahead on the open edges of the bevels. This will keep the bevels melting and flowing directly ahead of the advancing weld.

Avoid any circular or semicircular motion of the rod and torch. This action will create a large, loose puddle, very hard to control and subject to excessive

oxidation. Move the welding rod straight back and forth across the line of travel opposite the motions of the torch. The motion of the rod distributes the metal evenly across the weld and fills in the edges of the weld, thus preventing undercuts or rolled edges.

If possible, carry the weld puddle ahead in one pass, not moving ahead with a penetration bead unless the spacing of the pipe is very wide. Keep the bevels preheated to a sweating heat; and as the weld moves forward, pull the welding rod ahead into the throat of the weld to fill in the joint, and then move the rod back into the puddle. Using the crisscross stroke, keep the puddle as small and compact as possible.

As the weld progresses, the two pieces of pipe will draw together. If the welding is too slow or if sufficient spacing was not allowed during lining, the joint will become so close that it will be impossible to obtain good penetration. If this occurs, use the cutting torch to rebevel one side of the joint and open the vee to the correct size. Do not attempt to melt through a joint that is too close together, for this always results in poor penetration.

Start the weld small so that in finishing you can weld into both sides and the top of the beginning end of the weld. As the finish weld approaches the beginning end of the pipe weld, lift the rod from the puddle and play the torch flame against the cooled weld until the first $\frac{3}{8}$ in. is melted away and the bottom edges of the joint appear. Then bring the weld forward, and complete the tying in according to the usual finishing technique. You must be very careful in finishing a weld correctly, for most leaks in a pressure test occur at this point. Use the recommended starting technique if the weld must be stopped during its progress.

The weld should be fairly flat across the top, with the ripples closely spaced. The height of the weld should be not more than $\frac{1}{8}$ in. above the top surface of the pipe and not more than $\frac{1}{8}$ in. wider than the top edges of the bevels. There should be no undercuts or rolled edges. The penetration bead should be fairly uniform in shape and should extend through the joint about $\frac{5}{32}$ in. It must have no "icicles" or holes.

Make at least three consecutive 8-in. rolling pipe welds with the correct appearance, and be sure that 20 coupons from each weld pass the test before proceeding to the next lesson.

Lindeweld Process.—The Lindeweld technique is entirely different from any other technique of welding. Once it is thoroughly mastered, you will be able to make welded joints easily in all positions and will always be certain that the weld is 110 per cent strong. Lindewelding of pipe joints is about 50 per cent faster than the standard method of acetylene welding and is more economical owing to the saving in time and material.

The bevels on the pipe are cut to a 35-deg. angle instead of the customary 45-deg. angle. The pipe is rolled away from the operator during welding, with the weld progressing from the top to the bottom. The motion of the rod and torch is called the *accordion stroke.* The rod and torch are alternately pushed toward each other and pulled away to secure fusion and penetration and to form the weld.

A $\frac{5}{16}$-in. high-test welding rod instead of the $\frac{1}{4}$-in. rod is used to make this weld. An excess acetylene flame is used instead of the customary neutral flame.

Select two pieces of 8-in. standard line pipe about 12 in. long. Bevel one end of each pipe to a 35-deg. angle. Place the two pieces end to end in a straight line, with

the bevels facing each other. Leave about $\frac{3}{16}$ in. spacing between the bottom edges of the bevels. Tack-weld the joint in four places, equally spaced. Place the tacked joint on rollers or blocks so that it may be rolled easily. In order to take full advantage of the speed and economy of the Lindeweld process, be sure that the bevels are cut as smoothly as possible and that the spacing between the bevels does not vary.

FIG. 72.—Lindewelding. (*Courtesy of Linde Air Products Co.*)

Special Lindewelding tips are available having several flame holes in place of the regular one hole. This aids in keeping the joint well preheated ahead of the puddle and in keeping the rod melting and flowing (Fig. 72).

Use a $\frac{5}{16}$-in. high-test welding rod that is recommended for Lindewelding. Use a No. 6 welding tip or its equivalent, and set the regulator pressures at 10 lb. each. Light the torch, and adjust to a feather-edge (Fig. 73).

The excess acetylene flame used in making this weld deposits carbon along the joint. The preheated metal absorbs carbon readily, which gives the metal the same

characteristics as high-carbon steel. High-carbon steel melts more rapidly than mild steel. This accounts in part for the high welding speed attained in this process. It is necessary to have as great a volume of flame as the tip will produce.

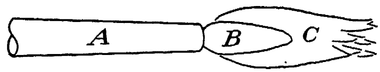


Fig. 73.—*A*, welding tip; *B*, inner cone of flame; *C*, heavy featheredge.

Hold the torch in the right hand, with the welding tip straight with the line of travel and pointing into the joint at a 45-deg. angle. Hold the welding rod in the left hand. Do not bend the rod unless it is necessary to do so to keep the hand out of the direct force of the

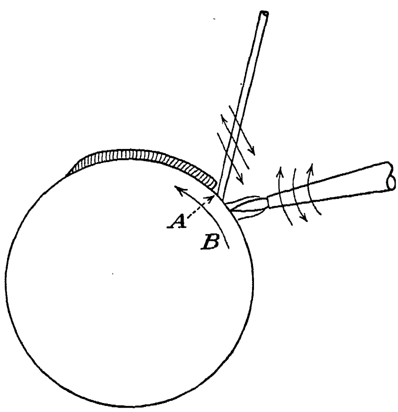


Fig. 74.—Rolling Lindeweld. *A*, position of puddle; *B*, direction of pipe movement.

welding flame. Keep the rod straight with the line of travel and pointing into the weld at a 30-deg. angle.

Begin the weld between two tacks on the top shoulder of the joint at about point *A* (Fig. 74). Roll the pipe away from you as the weld progresses, in order to keep the weld puddle at point *A*.

Preheat the bevels of the pipe to a sweating heat for about 3 in. along the joint ahead of the starting point. Do not attempt to heat the area outside the face of the bevels. Keep the welding rod near the welding flame so that it is molten as the joint approaches the melting point.

Move the torch back to the melting point. Heat the bevels until the face of the bevels begins to flow, drop the end of the welding rod into the puddle, melt off enough to fill the vee, and then move forward, using the accordion motion.

The torch is swung forward for about 1½ in., preheating the face of the bevels to a sweating heat, and then is swung back to the puddle and slightly up on the rod, keeping the rod and puddle melting and flowing together along the joint. The welding rod is moved forward in the vee about ¾ in. to meet the welding flame. As the flame moves ahead along the joint to preheat the bevels, the welding rod is drawn back about ⅝ in. against the top of the puddle, level with the top of the joint. Then the rod is moved forward again to meet the welding flame on its back swing. The action of drawing the rod straight back into the puddle fuses into the joint and fills the vee. The weld needs to be no more than $\frac{1}{16}$ in. above the top of the joint and only wide enough to guard against undercuts along the edge of the weld.

It is not necessary to melt deeply into the face of the bevels. However, the surface of the bevels must be melted away so that the fore edge of the advancing puddle flows along the joint like hot butter. As the point of the welding flame moves back to the puddle, it must be brought directly against the bottom edge of the puddle in the vee to ensure full fusion and penetra-

tion. Do not move the welding rod from side to side or use a semicircular or stirring motion. Do not draw the welding rod too high in the puddle on the pullback, or the weld surface will be peaked and rough. If the correct motion of the welding torch is used, the welding flame will extend past the welding rod over the surface of the area directly behind the advancing puddle and will aid in smoothing it.

If it is necessary to use more rod to fill the vee as the weld progresses, roll the rod back and forth between the thumb and fingers as it moves forward and back. This will cause a greater amount of welding rod to be deposited.

The bottom edges of the vee should never be closer than 1/8 in. It will be impossible to secure good penetration if the joint is too close. Use the cutting torch to open the vee if necessary.

If the surface of the bevels is rough owing to a torch cut, be sure to melt away the face of the bevels until all grooves or nicks are washed down. If this is not done, poor fusion will result along the edge of the weld.

As the weld approaches a tack, lift the welding rod out of the puddle and preheat the tack until it melts down into the bevels, and then bring the weld ahead.

If the weld is stopped during its progress, heat the puddle and bevels until the puddle begins to flow ahead, then add welding rod at the last highest point of the cooled puddle, and resume the weld, using the accordion motion. As the weld approaches the beginning end of the weld, lift the rod out of the puddle and melt away the first 5/16 in. of the end of the weld or to the point where clean smooth metal is reached. Then continue the weld, fusing well into the beginning end on both sides. Complete the weld.

The weld should be about 5/16 in. wide and flat across the top, with ripples close together. It should be about 1/16 in. above the top surface of the pipe. The penetration bead should extend through the joint about 3/32 in. and should be uniform in size, with no icicles or holes.

After you have learned to control the puddle and can make welds with the correct appearance, make at least two consecutive pipe welds with the Lindeweld process and cut 20 coupons from each weld. If every coupon passes the test, proceed to the next lesson. If one coupon fails, consider the entire weld a failure and continue practice.

Lesson 23

Making a Horizontal Pipe Butt Weld

Forehand Method.—Use two pieces of 8-in. standard line pipe, each about 12 in. long. Bevel one end of each pipe at a 35-deg. angle. Line and tack them in the form of a butt weld. Leave 3/32 in. spacing between the bottom edges of the bevels. Tack the joint in four places equally spaced, making small tacks.

Stand the pipe on end so that the weld is in a horizontal plane level with the shoulder. Use a No. 6 welding tip and a 1/4-in. high-test welding rod. Set the regulator pressure at 6 lb. each. Use a neutral welding flame.

This joint is to be welded according to the standard method, or forehand technique, of welding. The welding rod is held in the left hand and points into the weld at a 30-deg. angle. The upper end of the welding rod is held at a 30-deg. angle from the pipe (Fig. 75). The welding torch is held in the position recommended for horizontal welding. The barrel, or handle, of the welding torch is

moved forward so that the tip is pointed up toward the puddle at a 30-deg. angle and into the joint at a 45-deg. angle (Fig. 75).

Begin the weld between two tacks. Preheat the bevels to a sweating heat for about 2 in. ahead of the starting point. Move back to the starting point, and build up a small puddle. Move along the joint for 1 in., making a narrow deposit. Bring the weld to the correct size, and continue around the joint. The narrow beginning of the weld allows you to tie in to the weld during the finishing process without having a lumpy or thick joint.

The welding torch in its motion (Fig. 75) moves forward under the welding rod and pauses in the joint ahead of the puddle to ensure that both bevels are melting and flowing. Then the torch swings back in a small semicircular motion to the top of the puddle, which is 1/16 in. above the top edge of the joint. At this point, the torch flame fuses the welding rod into the top edge and melts a sufficient quantity of rod to fill the puddle. Then the torch moves forward under and ahead of the welding rod into the fore edge of the puddle.

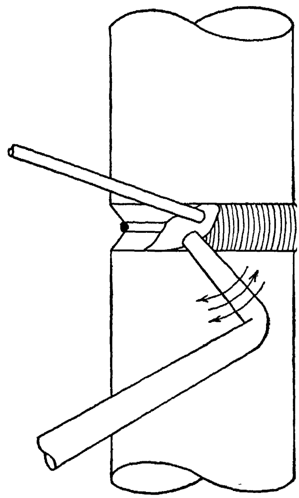


FIG. 75.—Horizontal pipe weld, forehand method.

It is important to realize that the torch flame, in its forward travel, fuses into the bottom bevel flush with the outside edge but does not melt the surface of the pipe outside the bottom edge of the bevel. This provides a shelf for the weld puddle and prevents sagging. The

forward motion of the welding flame draws the puddle along and smooths the bottom edge of the weld.

The welding rod is kept within the puddle at all times and moves in alternate strokes with the torch. It does not move the full width of the puddle but is moved in the top half of the weld puddle. It may be moved straight forward for about 5/8 in. in the line of travel whenever it is necessary to fill the crack and secure penetration.

The welding rod is moved in a full circular, or stirring, motion at the top of its upward travel (Fig. 76), adding extra metal at this point and keeping the face of the weld level. Use the regular finishing technique when tying in the weld.

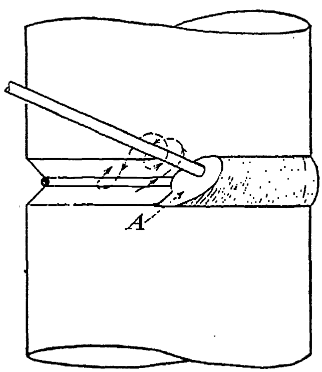


FIG. 76.—Arrows indicate rod movement.

The weld should be fairly flat across the face, with evenly spaced ripples and no undercuts or sagging edges. The penetration bead should extend through the joint for not less than 3/32 in. It should be uniform, with no icicles or holes.

Make two consecutive horizontal welds with the correct appearance and with 20 coupons from each weld passing the test before proceeding to another lesson (see Testing Weld Samples, page 229).

Lindeweld Process.—Line and tack two pieces of 8-in. standard line pipe, as in the last lesson, in the form of a butt weld to be made in the horizontal position.

Use a No. 6 welding tip, with the regulator pressures set at 10 lb. each. Use a 5/16-in. high-test welding rod

that is adaptable for Lindewelding. Start the weld between two tacks; and preheat the bevels to a sweating heat, using a featheredged flame, for about 2 in. along the line of travel ahead of the starting point. Hold the welding rod at a 30-deg. angle from the line of travel and at a 30-deg. angle from the pipe (Fig. 77). The welding tip should be held straight with the line of travel and pointed at about a 45-deg. angle into the weld (Fig. 77). Build up a small puddle, and move forward along the joint, using the Lindeweld technique. The rod is drawn back into the puddle and then at the end of the backstroke is pulled up slightly against the top edge of the joint, thus securing good fusion and preventing undercuts.

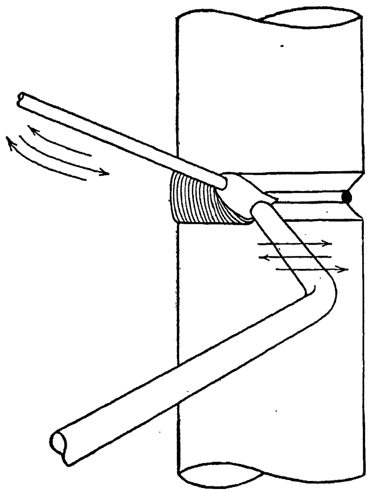


Fig. 77.—Horizontal pipe weld, Lindeweld process.

The torch motion is the same as that learned for the rolling weld. It swings forward, preheating the bevels to a sweating heat, then swings back to meet the advancing rod, melting off enough rod to build up the weld. Be sure that the point of the flame strikes the fore edge of the puddle in order to obtain full fusion and penetration. Keep the weld within the outside edges of the bevels. Carefully melt away the tack welds as the weld approaches them. Tie in the ends of the weld carefully.

The weld should be not more than 3/8 in. wide and should be fairly flat across the face, with smooth, evenly spaced ripples. There must be no undercuts or rolled

edges. The penetration bead should extend through the joint for about $\frac{3}{32}$ in. and should be free from icicles and holes.

With the Lindeweld technique, make at least two consecutive horizontal butt welds with the correct appearance and with 20 coupons from each weld passing the test before proceeding to another lesson.

Lesson 24

Making an Overhead Pipe Butt Weld

Forehand Method.—Line and tack two pieces of 8-in. standard line pipe in the form of a butt weld as in the preceding. Suspend the pipe horizontally 18 in. from the ground, with the weld in a vertical position. The weld is to be made by progressing from the bottom of the pipe up the side and finishing on the top of the joint. In this weld, the pipe is in a stationary position.

Use a No. 6 welding tip, with the regulator pressures set at 6 lb. each, and a $\frac{1}{4}$-in. high-test welding rod. Lie on the right side, if right-handed, facing the weld. Put a piece of cotton in the left ear to prevent sparks entering it. Move the right arm forward until you are lying on the back of the shoulder. This allows full freedom of motion of the arm. Hold the welding rod in the left hand, and bend the end of the rod at a 45-deg. angle about 8 in. from the end. This allows the rod to be held straight with the line of travel and pointing into the weld at a 30-deg. angle and keeps the hand out of the direct path of the flame (Fig. 78).

Start the weld between two tacks at a point just past the bottom center of the joint (Fig. 78). Make the first inch of the weld narrow and flat; then build it up to the correct size and bring it forward, using the crisscross

technique. Keep the bevels melting and flowing ahead of the advancing puddle, continually pushing the end of the welding rod deep into the joint just ahead of the puddle to obtain full penetration. Move the welding rod back into the puddle, using the crisscross stroke to distribute the weld metal. The same sized puddle with the same welding heat can be carried on the overhead weld as on the rolling weld. Remember that the weld metal will not fall until the puddle has become fluid enough to form a drop. The crisscross method, with the torch flame advancing steadily without going back again through the deposited metal, prevents the puddle growing too hot. The welding rod resting in the puddle at all times and moving in alternate strokes with the torch keeps the puddle from becoming fluid and dripping.

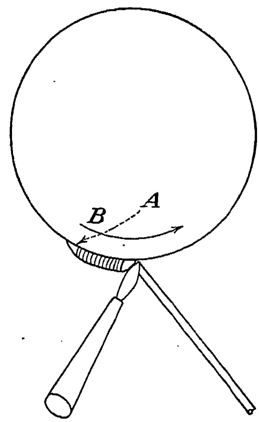


FIG. 78.—Overhead pipe weld, forehand method.

A spacing of ⅛ in. between the bottom edges of the bevels allows the weld metal to flow forward into the joint instead of piling up in the back of the puddle as it would if the joint were too close.

As the weld leaves the bottom of the pipe and starts up the side (Fig. 56), the most difficult welding area on a pipe weld is reached. Do not allow the welding flame to point up at the weld in this area, for this will make a long puddle that continually drips over the back edge. Keep the puddle as nearly level as possible.

As the weld starts across the top of the joint, the puddle will show a tendency to run ahead onto the cold bevels, causing very poor fusion and penetration. Keep

the welding rod nearly vertical from the weld and straight with the line of travel. The welding tip is straight with the line of travel and pointing ahead at a 30-deg. angle (Fig. 79). When this difficult area is reached, you may move ahead along the joint, making a sealing bead, and then drop back to the weld and bring it forward. This will ensure penetration and prevent bridging of the joint.

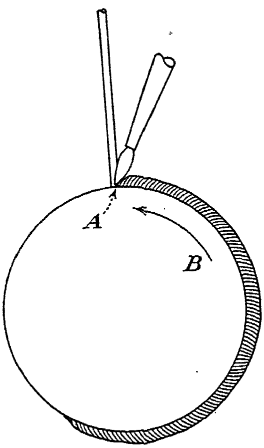


FIG. 79.—Position of rod and torch to complete weld. *A*, weld puddle; *B*, direction of welding.

Make the second half of the weld in the same manner as the first half. Start the weld on the bottom of the joint 1 in. back on the end of the previously deposited weld. Fuse well into the bead, and bring the weld across the bottom of the joint and up the side to the top, observing the same precautions as for the first half.

Be careful in making the tie-in on the top of the joint that there are no cold shuts or gas pockets left in the finish of the weld.

The weld should be about ½ in. wide, fairly flat across the top, and with no undercuts or rolled edges. The penetration bead should extend 3/32 in. through the joint, with no icicles or holes.

Make at least three consecutive overhead pipe butt welds with the correct appearance. Take 20 coupons from each weld, being sure to have one each from the bottom and top of the joint where the tie-ins were made. All these coupons must pass the tests before proceeding to another lesson.

Lindeweld Process.—Line and tack two pieces of 8-in. standard line pipe in the form of a butt weld. Suspend the joint as in the forehand method.

This weld is to be made with the Lindeweld technique, starting from the top and finishing on the bottom of the joint. Use a No. 6 welding tip, with the welding pressures set at 10 lb. each. Use a 5⁄16-in. high-test welding rod and a featheredge flame. Start the weld at the top of the joint between two tacks.

Preheat the bevels to a sweating heat for about 2 in. along the joint ahead of the starting point. Move back to the starting point, build up a puddle, and bring

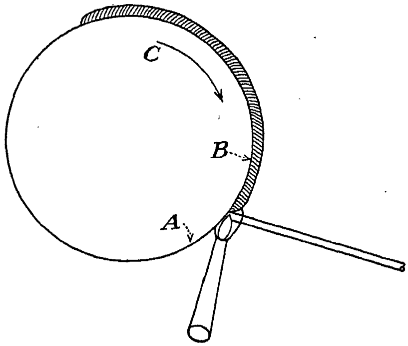


FIG. 80.—Overhead pipe weld, Lindeweld process. *A*, preheated area; *B*, weld; *C*, direction of welding.

the weld forward, using the Lindeweld technique, or accordion motion.

As the weld leaves the top shoulder of the pipe and starts down the side of the joint, the puddle will show a tendency to run ahead, bridging the crack and causing poor fusion and penetration. In order to overcome this condition, hold the welding rod at a 45-deg. angle from the joint instead of the customary 30-deg. angle. Lay the torch closer to the pipe so that the flame is pointing into the puddle at a 30-deg. angle instead of the customary 45-deg. angle (Fig. 80).

Use a shorter stroke with the welding torch, keeping the point of the welding flame driving against the fore

edge of the puddle. This action preheats the bevels to a melting point and forces the puddle into the joint, thus securing good fusion and penetration. Push the end of the welding rod deep into the joint, ensuring good penetration.

Alter the position of the torch and rod as the weld nears the lower quarter of the joint. This is the most difficult section of the weld.

Carry the weld across the bottom of the joint to a point past the bottom center. Observe the usual precautions in stopping and starting the weld to guard against cold shuts and gas pockets.

The weld should be not over 3/8 in. wide. It should be flat across the top, with the ripples smooth and closely spaced. There must be no undercuts or rolled edges. The penetration must extend through the joints for about 3/32 in. and must be free from icicles or holes.

Using the Lindeweld technique, make at least three consecutive overhead pipe butt welds with the correct appearance. Take 20 coupons from each weld. Each coupon must pass the test before proceeding to another lesson.

Lesson 25

Making a T, or Saddle, Weld

Forehand Method.—Select one piece of 8-in. standard line pipe 24 in. long and one piece 18 in. long. Trim one end of the 18-in. piece with a cutting torch so that it fits smoothly against the side of the 24-in. piece in the form of a T weld. Tack the joint in four places.

Use a 1/4-in. high-test welding rod and a No. 6 welding tip. Adjust the torch to a neutral flame. The welding procedure is exactly the same as for the T weld in Lesson 16.

The welds should be 5/8 in. wide, with no undercuts or rolled edges. The surface of the weld should be fairly flat, with evenly spaced ripples. Practice the T welds until you can make them well in all positions.

Lindeweld Process.—Line and tack two pieces of 8-in. standard pipe in the form of a T weld. Use a No. 6 welding tip and a 5/16-in. high-test steel welding rod. Set the regulator pressures at 8 lb. each, and adjust the torch to a featheredge. Use the Lindeweld technique and the accordion motion of rod and torch. You will find this joint much easier to weld by the Lindeweld process than by other methods.

Start the weld at the top of the joint, and progress down. If the joint can be turned, this will facilitate making the weld. If the joint is stationary, complete the weld as you did in Lesson 24.

Be sure to pull the welding rod against the vertical plate, or edge, at the top of the backstroke in order to deposit more metal along the top edge to prevent undercutting and to keep the face of the weld level. Keep the flat surface, or plate, preheated enough to maintain an equal melting rate between the edge plate and the flat surface. At all times keep the joint melting and flowing immediately ahead of the puddle.

Make T welds in the flat, vertical, and overhead positions until you have mastered the technique. The weld should be about 1/2 in. wide, fairly flat across the top, and with closely spaced ripples. The weld must be of uniform width around the joint.

Lesson 26

Making an Angle Weld

Use one piece of 8-in. standard line pipe 48 in. in length. Wrap the pattern around the pipe, and mark

the angle with sharp soapstone (Fig. 81). Hold the cutting torch so that the tip points at right angles to the chalk mark, and cut the joint in two, leaving the edges of the pipe square as though cut with a saw. Cut a 35-deg. bevel on the ends just cut. Leave 1/16 in. uncut along the bottom edge of each bevel (Fig. 82).

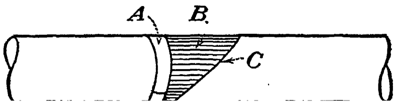


FIG. 81.—*A*, base of pattern; *B*, pattern; *C*, line to be cut.

This method of cutting prevents waste of material and protects the over-all measurement.

Place the joints end to end, forming a 90-deg. angle (Fig. 83). *A* is the throat of the weld, *C* is its point, and *B* and *D* are the side center points.

Remember that an angle weld will always draw, or shrink, in the throat when the weld cools. This condition must be allowed for in the spacing of the joint during lining up. Space the joint about 3/16 in. apart between the bottom edges of the bevels. Check the angle with a steel square to be sure the joint is lined exactly at a 90-deg. angle.

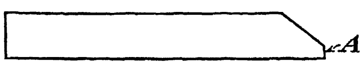


FIG. 82.—*A*, unbeveled area.

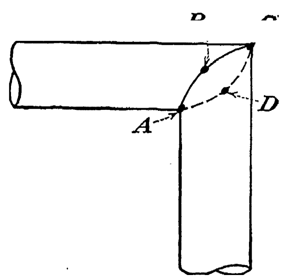


FIG. 83.—Angle weld.

Space the legs of the angle until the spacing in the throat is 5/16 in. wide and the spacing at the point 3/16 in. This allows 1/8 in. for the normal contraction of the weld. The rate of contraction varies with the speed of welding and the size of the weld. The slower the weld is made

and the greater the weld deposit, the greater the amount of contraction. Experimenting will show the exact distance to offset the joint for the weld to pull straight after cooling.

Tack-weld the angle at the point (Fig. 83). This exerts a pull on the joint and tends to open the throat of the weld. Tack-weld the two side centers; last, tack-weld the throat.

If the joint can be turned, weld continuously from point *B*, through points *C*, *D*, *A*, and finish at point *B*. If necessary, additional pull may be exerted on the joint by welding from point *B* to point *C* and from point *D* to point *C*. Then weld from point *B*, through point *A*, and finish at point *D*. Do not stop or start the weld in the throat of the angle, since a weld tends to shrink toward the finishing point.

Either the forehand or the Lindeweld technique may be used to make this weld. It is well to practice it with both methods. Remember that the point needs very little rod compared with the rest of the weld. Its shape is that of an edge weld, and in order to keep it the same width the edges of the joint are melted down deeply. Across the side-center areas the joint is a regular butt weld. The throat requires much heat and rod to obtain the necessary fusion and penetration and to build the weld up to the correct size.

The penetration bead should extend through the joint for at least ⅛ in. It should be free from icicles and holes. The weld should be of uniform width around the joint and fairly flat across the top, with evenly spaced ripples. There must be no undercuts or rolled edges.

Make at least three angle welds and test coupons from the throat and point of each weld before proceeding to another lesson.

Lesson 27

Making a Pattern Layout

Welded pipe installations require welded fittings. Many of these fittings, such as tube turns and reducers, may be purchased from the manufacturer, but often the welder must make his own fittings. Fittings generally involve angles, T welds or headers; swages, or reducers; and bull plugs.

To fabricate a fitting to fit exactly requires a pattern. There are good pattern-layout books available that give in detail the step-by-step method of laying out intricate patterns.

The method of making a pattern discussed in this lesson is for the welder who does not have a combination square, a protractor, or dividers available when it is necessary to lay out an angle. Every welder must have, in addition to the other tools of his trade, a center punch, a 2-ft. steel square, and a level at least 18 in. long. These implements are necessary whenever any type of joint or fitting is to be fabricated.

Lay out the pattern on any heavy paper, and keep it for future use. The pattern may be laid out on any flat surface and the information transferred to the pipe by lines drawn to match the lines drawn for the pattern.

In making a pattern in this way it is not necessary to know the exact degree of the angle needed. Simply bend a welding rod to fit the angle (Fig. 84). Place the welding rod on the flat surface, and with a sharp piece of soapstone draw a line along the rod, *A* to *B* to *C*.

Bisect the angle at point *B*. If you do not have a pair of dividers, use a string and a nail and a piece of sharp soapstone (Fig. 85). With point *B* as a center,

lay off points P and S equidistant from point B; with point S as a center and any length greater than the distance BS, scribe arc LN; use the same length string, and scribe arc MO, using point P as a center. Now

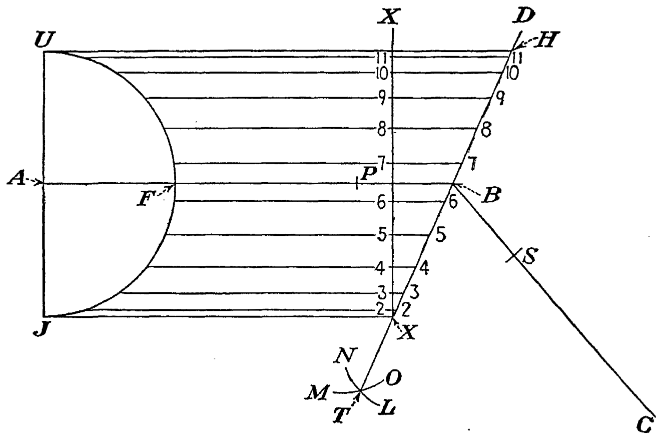


FIG. 84.—Pattern layout for cutting an angle.

draw a line from the intersection of the two arcs at point T, through point B, and on to point D. Line TBD bisects the angle at point B. Lines AU, AJ, AF are the radius lines of the circle.

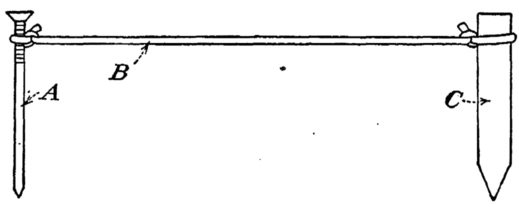


FIG. 85.—*A*, nail; *B*, string; *C*, soapstone.

On line AB, draw line UJ equal to the outside diameter of the pipe you are working on. Line UJ must be at right angles to line AB.

Set the nail at point *A* and the chalk at point *U*. Scribe a half circle to point *J*. This represents half the pipe.

Divide the half circle into any number of equal parts. Use at least 11 divisions. Now, draw a line from point *U*, parallel to line *AB*, across to line *TBD*. Continue around the half circle, extending lines from all points on the half circle parallel to line *AB*, across to line *TBD*.

Where the line from point *J* intercepts line *TBD* at point *X*, erect a perpendicular line *XX*, cutting across the horizontal lines just drawn.

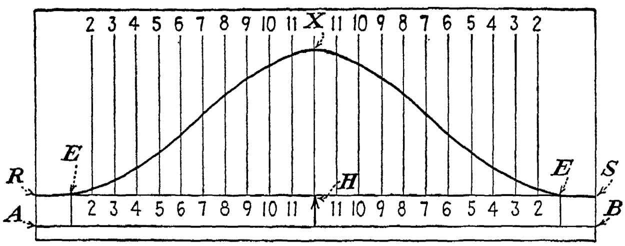


FIG. 86.—Pattern marked for cutting.

On the heavy pattern paper draw two lines *RS* and *AB*, 3 in. apart and parallel with each other. They should be 4 in. longer than the outside circumference of the pipe you are working on (Fig. 86).

Mark points *E*, *E* 2 in. in from each end on line *RS*. Line *EHE* is the exact distance around the pipe and is the base line of the pattern. Locate point *H* halfway between points *EE*. Since the pattern layout (Fig. 84) represents half the circumference of the pipe, divide line *EH* (Fig. 86) into the same number of parts as the half circle (Fig. 84).

Complete the division of line *HE* into the same number of parts as line *EH*. From point *H* erect a line *HX* perpendicular to line *EE*. This line corresponds to the

line *HX* in Fig. 84 and is the center of the pattern. Erect perpendicular lines from all points on line *EE* approximately as long as line *HX*.

Work both ways from line *HX*, and lay out the distances marked by numbers 2-2, 3-3, 4-4, etc., in Fig. 84, on the perpendicular lines of the same number, in Fig. 86. For example, the distance marked by 7-7 (Fig. 84) would be laid out on the perpendicular line extending from point 7 on the base line. Use a hack-saw blade, and, connecting three points at a time, draw a line through all the points just marked.

Cut the paper along line *AB*. Cut from *RE* through point *X* to point *E* to point *S*, completing the pattern.

Before you can use the pattern accurately, you must locate center lines on the pipe. Place the pipe on blocks, and level (Fig. 87). In order to find the top center point, stand a level vertically beside the pipe with the top bubble within its marks (Fig. 87). Slide a 2-ft. square across the pipe and against the level. Mark the top center of the pipe. Place the level in a vertical position in front of the end of the pipe against the top center mark. When the bubble in the top of the level is within its marks, place a mark on the bottom edge of the pipe beside the level. This is the bottom center of the pipe.

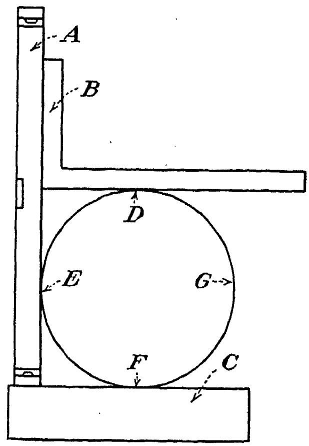


FIG. 87.—*A*, level; *B*, square; *C*, block; *D,E,F*, center points.

Roll the pipe over until the points just located are on the sides, and level, in a horizontal plane. Now locate

the top and bottom center points again, and you will have four center points accurately located.

In making a T joint, or saddle weld, without a pattern, place one piece of pipe on the other, being sure that the center points match (Fig. 88). Place a square against a vertical pipe, and let it slide down until it just touches the bottom pipe (Fig. 88). Check the measurement from A to B. Measure C to D. Be sure the measurements are identical. Mark off on line RS the same distances as A to B. Draw a line from A to S to C, following as closely as possible the curve of the lower pipe.

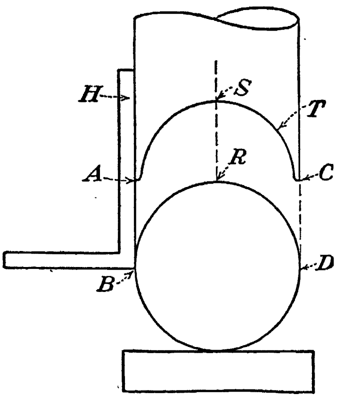


Fig. 88.—Method of marking saddle cut.

Cut both sides of the vertical pipe, and allow it to slip down over the lower pipe. Both points of the vertical pipe at A and C must be rounded to allow it to fit snugly against the lower pipe. Draw a chalk line around the vertical pipe on the bottom pipe. Remove the vertical pipe, and cut out the saddle patch. Bevel both edges for welding, and proceed as outlined in Lesson 25.

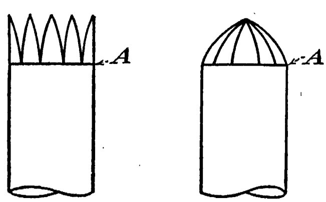


Fig. 89.—Orange-peel bull plug. A, base line.

If it is necessary to close the end of a pipe, use the orange-peel bull plug (Fig. 89). There are two other means of closing the end of a pipe, the bullnose bull plug (Fig. 90), and the flat end (Fig. 91). Of the three methods, the orange-peel bull plug is recommended as

being the best for high-pressure work. Closing the end of a pipe with a flat plate is not good practice and is not allowed where pressure is involved. In making an orange-peel plug, cut the end of the pipe into not less than 7 sections, always using an uneven number of sections, 7, 9, 11, 13, etc.

In order to determine, without a pattern, how much to cut out to form a plug, divide the outside circumference by the number of cuts desired. The length of the cuts depends upon the diameter of the pipe. The larger the diameter of the pipe, the longer the cuts must be in order to retain the tapered shape of the bull plug.

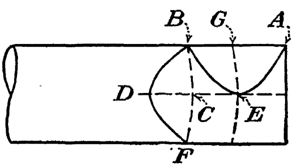


FIG. 90.—Layout of bullnose bull plug.

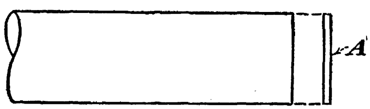


FIG. 91.—Pipe closed with flat end. *A*, steel plate.

After the cuts are made, hammer the pointed ends together, being sure that they meet in the center of the end of the pipe (Fig. 89). Tack and weld on alternate sides of the pipe, welding from the base of the cuts to the points. Peen the end of the weld to smooth it and to eliminate any gas pockets.

If a bullnose bull plug is specified, lay off a line *AB* along the top of the pipe equal to the outside diameter of the pipe (Fig. 90). Locate point *G* halfway between *B* and *A*. Draw a straight line around the pipe at points *B* and *G*. Locate the two side center points, and extend the lines back from these points along the joint on both sides for 18 in. Locate points *C* and *E* at the intersections of the parallel and roundabout lines. Locate two points on the opposite side of the pipe to

correspond to points *C* and *E* (Fig. 90). Draw a line from point *B* to *E* and from point *A* to *E*. Draw corresponding lines on the opposite side of the pipe. Measure from point *C*, along the center line for a distance equal to half the outside diameter of the pipe, to point *D*. Draw lines from *B* to *D* and from *F* to *D*. Draw corresponding lines on the opposite side of the pipe.

Cut from *F* to *D*, to *B*, to *E*, to *A*. Cut through corresponding points on the opposite side of the pipe, leaving about ½ in. at point *B*. Heat point *B*, and fold down the cap *BEA* to fit into the section *BDF*. Care must be exercised to make the cuts match to facilitate welding.

A swage, or reducer, is used to weld one pipe of large diameter to a pipe of small diameter. A variation of the orange-peel bull plug is used to form a swage. A simple method to determine the measurements of the swage is to subtract the outside circumference of the small pipe from the outside circumference of the large pipe. Divide the difference by the number of cuts desired, and the result will be the exact amount to cut away at each point.

In making a swage joint, bend the sections to the desired diameter. Tack all the splits. Then line and tack the smaller pipe to the end of the swage joint. Weld all the splits down to the roundabout weld. Then make the roundabout weld, tying in the ends of the lengthwise welds.

On all joints of this type, be sure to use at least seven splits to make the swage. Always use an uneven number of cuts in making swage joints or orange-peel bull plugs.

CHAPTER VII

IDENTIFICATION OF METALS

Before preparing a job for welding, it is necessary to identify the metal in order to determine the type of welding process necessary to do the job. There are eight types of metal commonly encountered in welding. They are gray cast iron; white, or chilled, cast iron; malleable iron; mild steel; aluminum; pot metal; brass; and copper.

It may be possible to determine the type of metal from the external appearance of the break. The inner surface of a break in white cast iron will show a white, close-grained surface with a dark layer on the outside. If the metal is gray cast iron, the inner surface of the break will be dark and coarse-grained.

To determine whether or not the metal is cast iron, play the flame of the welding torch over an outside corner or edge. As the metal begins to grow red, many small sparks will appear under the flame. As the heat is increased, the metal becomes a light straw color and will begin to swell and shift. Cast iron will attempt to flow, but it has a heavy oxide surface which prevents melting and flowing unless flux is added.

If the metal is malleable iron, it will become nearly white under the flame before melting. There will be a number of minute sparks under the flame. Even though the metal will puddle under the flame, in this respect resembling mild steel, there is a characteristic scum over the puddle and around the edges.

Mild steel, under the welding flame, will grow red, light red, and finally white. At this point the metal will begin to melt. The mild-steel puddle is free from sparking and is clean and shiny in appearance. The reflection of the welding flame may be seen in the puddle.

Aluminum and pot metal are similar in appearance. Aluminum is much lighter in weight although this is not always a positive means of identification. Neither aluminum nor pot metal will change color under heat. Both metals will collapse without change of appearance under the direct force of the welding flame. When the torch flame is played carefully on aluminum, the metal shows the same signs of shifting under the flame as cast iron. There is a heavy oxide on aluminum, also, which must be removed by a flux. As the heat grows in the aluminum, the metal will occasionally sag. There may be a checking in the skin of the metal under the flame.

When pot metal is heated, the outside surface will resist more heat than the interior. The outer skin will wrinkle and finally check, allowing the inner metal to bubble through the checks in round globules.

Brass and copper may be distinguished from each other by the fact that copper takes much more heat to melt than does brass. The weld puddle in copper will cool instantly when the flame is removed, whereas the puddle in brass will remain fluid much longer. The reflected flame from copper is definitely green. The reflected flame from brass is yellow tinged with blue.

CHAPTER VIII

EXPANSION AND CONTRACTION

When metal is heated, it grows, or stretches. This action is called *expansion*. As the metal cools, it shrinks, or contracts. This action is called *contraction*. An important point to remember is that the cooling metal will contract slightly more than it expanded.

Contraction sets up a strain in the metal that is referred to as *locked-up stress* or *residual stress*. Contraction and expansion stresses cannot be eliminated, but they may be controlled by making adequate allowance for the movements of the metal under the heat.

While cooling, the weld metal has a tendency to shrink more than the parent metal. Thus the weld is *in tension*, that is, is pulling itself away from the parent metal. The ideal situation is for the weld to be *in compression*, that is, to be in a condition in which the parent metal is pressing upon the weld. This action will eliminate distortion, locked-up stress, and subsequent cracking of the weld or the parent metal after cooling.

There are two procedures that may be used to offset or neutralize expansion or contraction. The first and simplest method is the spacing of the joints to be welded to allow the metal to contract normally. Figure 92 shows two ¼-in. mild-steel plates 12 by 6 in. The two plates were placed close together and welded without tacking. The plates drew together as the weld progressed until one plate was lapped over the other.

This may be partly remedied by tack welding the joint before welding. However, the outside edges of the plates will draw out of a straight line toward the top

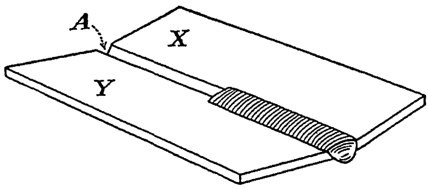


FIG. 92.—Plates welded without tacking. *A*, joint; plate *X* lapped over plate *Y*.

surface of the weld. The plates will follow the direction of the pull caused by the cooling weld.

If the plates are spaced about $\frac{3}{16}$ in. to the linear foot (Fig. 93), they will draw together as the weld progresses. Experience will show exactly how much spacing to allow since the size of the weld and the speed of welding affect the contracting rate of the joint. With this procedure the plates should not be warped, or drawn out of line, since allowance was made for the contracting action of the weld.

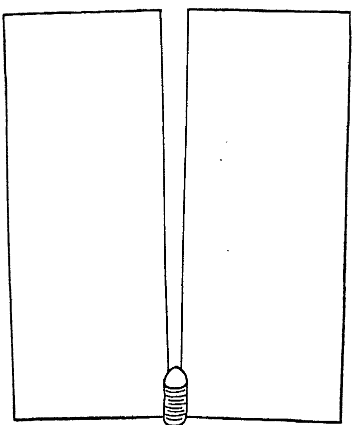


FIG. 93.—Plates spaced for welding to offset contraction.

The second method of control is to remove the heat from the joint as the weld progresses, keeping distortion to a minimum and practically eliminating locked-up stress. In this method, chill bars and blocks are used. In Fig. 94, two sheets are being welded together. Notice the chill bars on each

side of the joint. These bars draw the heat from the weld, thus preventing the spreading of heat into the plates to cause warping or distortion. The bottom chill bar has a vee groove cut along its length. The vee is placed directly under the joint, allowing room for the penetration bead.

The greatest difficulty presented by expansion and contraction is encountered in the welding of such cast-iron objects as gear wheels, cylinder heads, and automobile blocks. On welding jobs of this type, heat is used to control the expansion and contraction so that the weld is left in compression rather than in tension.

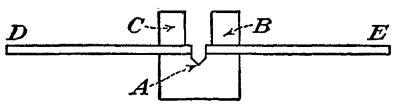


FIG. 94.—Method of drawing heat from plates during welding. *A*, vee to to allow for penetration bead; *B*,*C*, chill bars; *D*,*E*, plates to be welded.

This method involves preheating the area around the break to expand the casting. The heat in the casting is regulated so that the casting remains expanded to its fullest capacity. The weld is then made according to the regular welding procedure. The heat in the weld is allowed to drop slightly while the heat in the casting is maintained. Then the preheating agent is removed, and the entire casting is allowed to cool.

Visualize what has occurred. The casting was opened, or expanded. The weld was put in and allowed to begin to shrink while the casting was held open. Then the casting was allowed to cool. The body of the weld has a tendency to hold the joint apart. The casting, in shrinking, crushes against the weld, setting up a most desirable condition. The weld is in compression and not in tension. That is, there is no residual stress set up in the casting, and the weld is not attempting

to pull away from the body of the casting, an action that would cause cracking or distortion.

Figure 95 shows a gear wheel with a broken spoke. If the crack is veed out and welded with no preheating precautions, the weld will be left in tension. The spoke will attempt to shrink, and the rest of the gear will resist. Locked-up stress will result, and after the gear is back in service it will probably crack beside the weld or in the outer rim. The casting must be opened and held open while the weld is put in.

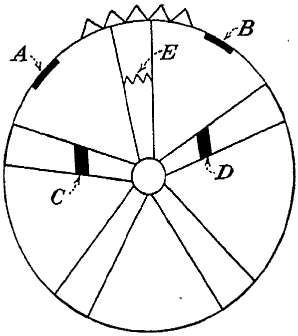


FIG. 95.—*A,B,C,D* indicate order of preheating fracture, *E*.

Play the torch over the casting until the chill is gone. Then preheat at points *A* and *B*. Do not let the heat in the casting rise above a black heat. Heating at these points will cause the rim to pull out from the hub, which will open the crack in the spoke.

Continue preheating at points *C* and *D*. This adds in expanding the joint and removes the strain on the spokes caused by expanding at points *A* and *B*.

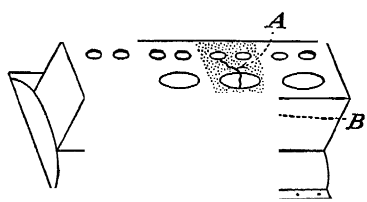


FIG. 96.—*A*, crack from valve seat to cylinder; *B*, shaded area, indicates preheated area.

Vee out the joint, and weld. Remember to keep the casting expanded during welding. When the weld is completed, preheat the points *A*, *B*, *C*, *D* for a period of 1 min., allowing the heat in the weld to drop. Then remove the preheating agent from the gear. Cover the

casting to prevent sudden chilling, and let it remain covered until the heat is gone.

No matter where the breaks occur in the gear, use the same system of opening the casting and putting in the weld. If there are several cracks, work from the center of the gear to the outside.

This system of leaving the weld in compression applies to any casting. For example, an automobile block that has a crack running through the valve seat, across the top of the block, and down the cylinder wall (Fig. 96) is difficult to weld, but with proper control of expansion and contraction the job will be successful.

With this system it is not necessary to pack the casting in sand or asbestos. The formerly accepted method was to preheat for hours until the entire casting reached a red heat. Then the joint was welded and the casting allowed to cool in sand or asbestos. The difficulty with this method is that the weld and the casting are brought to the same heat but there is a difference in the cooling rate of the weld and the casting, which often produces distortion or cracking.

CHAPTER IX

CAST-IRON WELDING AND CUTTING

Cast-iron welding involves the same basic principles of fusion and penetration as the welding of mild steel. The joint must be veed out, and the base metal and rod melted and flowed together. The difference between cast-iron welding and the welding of mild steel is that the cast iron has a heavy surface oxide, which must be removed with a good cast-iron flux as the weld is made.

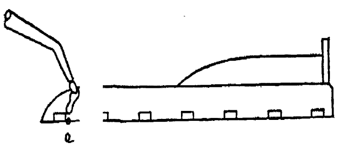


FIG. 97.

An old cylinder head or junk automobile block makes good practice material. The controlling of expansion and contraction need not be a consideration at this point, for only the actual weld will be discussed here.

Use a No. 4 welding tip, with the regulator pressures set at 10 lb. for the oxygen and 5 lb. for the acetylene. Select a good cast-iron welding flux and a good 1/8-in. cast-iron rod. Place the cylinder head on the welding bench face down. Light and adjust the torch to a neutral flame. Preheat an area 1/2 in. wide and 1 1/2 in. long up and down one corner of the cylinder head (Fig. 97). The weld is to be made in a vertical position.

Preheat the area to just under a red heat. Hold the point of the welding flame against the top of the cylinder head so that the flame is pointing down (Fig. 97). When the area under the flame becomes red and begins to swell under the heat, turn the oxygen valve wide

open. This produces a harsh driving flame with very little heat. Use this flame to gouge or chisel out the vee to be welded. The excess oxygen unites with the hot metal to oxidize or burn it, and the force of the flame drives the molten metal from the puddle. If the cut stops, turn the oxygen back until a neutral flame is reached, preheat to a red heat, and resume the cut. This system of veeing out cast iron is satisfactory for the acetylene-welding, arc-welding, and brazing processes.

When veeing out a crack, examine the cut closely as it progresses. There will be a fine gold line indicating the fracture. Follow this gold line with the torch, and vee out until the gold line stops. Then vee the crack ¼ in. farther to be sure that the entire fracture is exposed. Make a check to be sure that the fracture did not turn at a sharp angle. Preheat the area to a bright red heat around the end of the vee. Pull the torch away. If the crack continues, it will be apparent as a thin black line on the surface.

Adjust the regulator pressures to 4 lb. each, and adjust the torch to a slightly oxidizing flame. An oxidizing flame is used instead of a neutral flame because it is necessary to use a driving, or penetrating, flame on cast iron. The driving flame also assists in decreasing the gas pockets or acetylene "bugs" left during welding.

Preheat an area at the lower end of the vee to a bright red heat and until the metal under the flame is swelling. Keep the flame pointed directly into the puddle, heat the end of the welding rod, and dip it into the can of flux. Bring the fluxed end of the rod to the puddle, and melt the flux into it. As soon as the flux is absorbed, the molten puddle will become as clean and fluid as a mild-steel puddle. Keep the torch flame pointing directly into the puddle, and dip the end of the rod into the flux

can. Bring the end of the rod just to the surface of the molten puddle, and melt off a small amount. Move the torch from side to side with a crisscross motion, and fuse the deposit and puddle thoroughly. Do not push the end of the rod into the puddle, for this will create a cold spot in the weld. Add more rod, and proceed as outlined.

Always keep flux on the welding rod during welding. Keep the torch flame pointed directly into the puddle at all times. Cast iron will absorb much more heat than steel without damage to the casting. Carbon is released in cast iron in the form of a gas. There is always a certain amount of acetylene gas forced into the puddle that escapes through the molten metal. Keeping the puddle active and in motion allows the gas to escape without leaving holes in the weld. If an examination of the weld shows any honeycomb, wash the puddle thoroughly with an oxidizing flame, adding a little flux until the holes are removed.

When the cast-iron weld is finished, it may be smoothed flush with the surface of the casting by bringing the weld to a molten state and scraping the surplus metal away with an old file or a welding rod.

To avoid undercuts along the edge of the weld, move the flame back over the last finished 1½ in. of the weld, heating the casting to a molten state. Then move the torch along the edge of the weld with the flame pointing toward the edge of the weld and away from the center. The weld metal will flow under the surface oxide into the plate, filling up any undercuts and smoothing the weld.

In making a machinable cast-iron weld do not allow the weld to cool suddenly. In building up a valve seat, keep the area for at least 1 in. around the valve seat a bright red during welding. Hold the bright red heat in

this area for 1 min. after the heat color in the weld has begun to drop. Hard spots in the weld will result if the heat is not held up in the casting around the weld.

If the cutting torch is used to cut, or scarf, cast iron, adjust the flame to a featheredge. Preheat the area

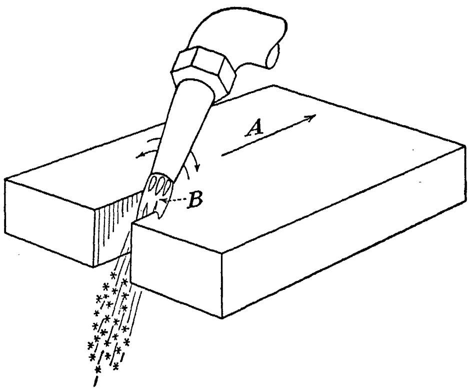


FIG. 98.—Arrows indicate motion of torch. *A*, direction of cut; *B*, carburizing flame.

thoroughly where the cut is to start. Point the cutting tip back instead of forward as is done in mild-steel cutting (Fig. 98). As the area under the cutting flame grows hot, press the high-pressure oxygen trigger gently, move the torch in a half circle, and wash away the molten metal.

CHAPTER X

HARD FACING AND ALLOY WELDING

HARD FACING

To hard-face means to deposit a thin overlay of extremely hard metal on the surface of the part that is exposed to wear. There are two types of wearing, one caused by a sliding, or abrasive, action, the other by impact, as in a stamp mill.

Practice with an abrasive-resistant rod first. Use a piece of ¼- by 2-in. mild-steel stock about 12 in. in length. Grind the surface smooth to remove dirt and rust, and place the iron on the bench. Use a No. 4 welding tip, with the regulator pressures set at 4 lb. each. Use a $\frac{3}{16}$-in. hard-facing rod. Light and adjust the torch to a heavy featheredge. The featheredge deposits carbon, which aids in bringing the surface of the metal to a sweating heat and increases the hardness of the deposit.

Play the flame on the end of the plate, in an area about ⅝ in. in diameter, until the area turns white and begins to sweat. Melt a little rod onto the plate, and smooth it across the heated area. Lift the rod out of the puddle, preheat the plate in front of the deposit, add more rod, and fuse it into the plate and the previously deposited metal. Do not melt too deeply into the base plate. The deposit of hard metal is very thin, not over $\frac{1}{16}$ in. If the base metal is melted too deeply, it will dilute the hard metal, leaving soft spots.

The surface of any hard-facing deposit must be smooth and uniform in height. Make the deposit very smooth, with no ridges in the surface.

On a surface subjected to a pounding, or impact, action, use a hard-facing rod designed for this type of wear and deposit it in the same manner as the abrasive rod. The impact rod deposit will be thicker and possibly rougher; after 1½ in. has been deposited, use a peen hammer and hammer the deposit thoroughly. This action not only will smooth the deposit, leaving a uniform surface, but will increase the hardness of the deposit. The pounding, or impact, action while the part is in service will also harden the deposit.

ALUMINUM WELDING

Aluminum has several welding characteristics similar to those of cast iron. Both metals have a heavy surface oxide, which must be removed with a flux during welding, and both metals are subject to distortion and cracking through sudden heat changes.

Aluminum does not change color under the flame. Generally, there is no change apparent to the beginner until the area under the torch suddenly falls away.

An aluminum cylinder head offers good practice on cast aluminum, and sheets or strips of drawn aluminum are also very satisfactory. At this point, consideration need not be given to expansion and contraction. Only the actual weld is to be discussed here.

Place the cylinder head upon the bench face down. Vee out a groove to be welded. There are four methods of veeing out the crack preparatory to welding: (1) A diamond-point chisel may be used if the part to be welded will stand the impact of the hammer and chisel. (2) The crack may be veed out on the grinder if the shape

allows. (3) A welding torch may be used to vee the crack by the same procedure as that outlined in Chap. IX. (4) A welding torch may be used to preheat the joint; then a bronze welding rod, with an end shaped in paddle form, is used to scrape away the excess metal and vee out the crack.

Make the weld in a vertical position. Use a No. 4 welding tip, with the regulator pressures set at 5 lb. each. Use a 1/8-in. aluminum welding rod and a can of good aluminum welding flux. Light and adjust the flame to a slight featheredge. Hydrogen gas may be used instead of acetylene gas; in this case, adjust the torch to a neutral flame.

In order to see the puddle clearly while aluminum welding, use a lighter shade of lens in your goggles than for other types of welding (No. 4 cobalt blue).

Point the flame straight into the lower end of the crack, or vee, and preheat an area about 1 in. along the joint. Heat the end of the welding rod for about 1 in., and dip it in the flux. The flux will adhere to the heated rod.

A very successful method of applying flux is to mix a paste of aluminum flux, alcohol, and distilled water and, using a small paintbrush, paint the flux on both sides of the joint to be welded and on the welding rod. To remove the flux applied in this manner, soak the welded piece 1 hr. in a 10 per cent solution of sulphuric acid. Then soak the piece in clear water for 4 hr.

Watch the joint closely, and you will notice that the surface of the aluminum will swell under the flame very much like cast iron. When this occurs, melt the flux from the rod into the puddle and dip the rod into the flux again. Bring the end of the rod to the puddle, and melt off a small deposit. Keep the flame playing on the puddle, again dip the rod in the flux, and repeat the

process. Be sure to obtain full fusion and penetration. Use the same crisscross motion of the rod and torch as that used in mild-steel welding.

If aluminum plates are to be welded together, bevel or space them just as for mild-steel plates. Grind or clean away the oxide on each side of the joint for ¼ in. Use the same procedure as that outlined on page 120.

There is a technique in welding aluminum similar to that described on page 51. The rod is dragged ahead in the joint, breaking down its walls; then the rod is moved back into the puddle, the torch is moved forward to meet it, a small amount of rod is melted off, and the rod is dragged ahead into the joint. The flame moves down into the puddle and back in the joint about ½ in., obtaining full fusion and penetration. Then the rod and torch are again swung to meet each other (Fig. 99).

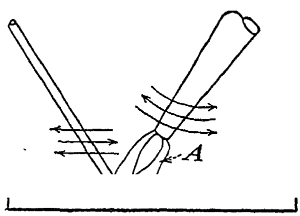


FIG. 99.—Arrows indicate motion of rod and torch. *A*, carburizing flame.

Lock all aluminum welds to prevent the parent metal or the weld cracking from the edge.

ALUMINUM ZINC DIE-CASTING ALLOYS (POT METAL)

Door handles for automobiles, radiator ornaments, horn brackets, and phonograph parts are often made of a soft, heavy material called *pot metal*. Welding rods for pot metal are available on the market. However, a rod may be made by melting scrap or broken parts of the metal into an angle iron turned up to form a trough. The pot metal will flow along the angle iron, forming a thin pot-metal rod.

When a pot-metal handle is to be welded, grind the broken edges to a 30-deg. bevel and grind any plating

away from the edges of the joint for about ¼ in. Leave about 1/16 in. along the bottom edge of the joint unground. Place the handle on the bench, and line it for welding. Block the piece until it cannot sag when heat is applied.

Use a piece of ⅛-in. bronze welding rod, and hammer and grind one end to a small paddle form. Use a No. 1 welding tip, with the regulator pressures set at 1 lb. each. Light the torch, and turn on just enough oxygen to remove the smoky edges of the flame. This leaves a soft acetylene flame, slightly tempered with oxygen, about 1½ in. long.

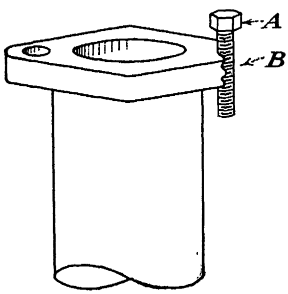


FIG. 100.—*A*, studbolt; *B*, area to be built in.

You will not be able to see this weld with the regular welding lens in your goggles. Remove the dark lens, leaving the clear lens to protect the eyes from flying particles of metal.

Play the point of the flame across the joint. The face of the bevels will begin to move. Lift the point of the flame out of the puddle, and with the paddle end of the bronze rod mix the molten metal in the joint. Be sure that you obtain full fusion through the joint from one side. If possible, avoid back welding. When you raise the flame out of the puddle, be sure that it does not play against another section of the job as you use the paddle. If this is done, the section under the heat may suddenly

Now use the pot-metal rod, and weld the joint as for any fusion-welding job. Smooth the weld with the paddle and flame.

Often in repairing a carburetor or a washing-machine part you will find that the break has occurred through a

stud bolthole (Fig. 100). Insert the stud bolt in its proper location, and build in around the bolt with the pot-metal rod. The pot metal melts at such a low temperature that the stud bolt will not become heated enough to change color. As soon as the weld is completed, screw the stud bolt slowly out of the hole. Good threads will remain in the hole.

STAINLESS-STEEL WELDING

Stainless steel has a smoother, higher polished surface than mild steel and may easily be distinguished from it. Inconel and monel are distinguished from ordinary stainless steel by their light, highly polished surface and by the fact that they will flow under the welding flame with little or no sparking, while common stainless steel if melted without the addition of flux will oxidize rapidly, with profuse sparking.

Select two pieces of 0.065-in. stainless-steel plate, and line them in the form of a butt weld. Use a No. 2 welding tip, with the regulator pressures set at 2 lb. each. Use a $\frac{3}{32}$-in. stainless-steel welding rod.

Mix a welding flux, using Fulgham pure white shellac, 4 lb. cut, and stainless-steel welding flux. Mix to a thick paste; then thin to a medium paste with alcohol. Paint the rod with the flux, and allow it to dry. Tack-weld each end of the joint, using a slightly carburizing flame (a slightly featheredged flame). Paint the bottom side of the joint evenly with the flux, and allow it to dry before welding. If the welding must be done before the flux dries normally, play the torch over the flux. It will catch fire and burn, drying and solidifying.

Preheat an area for about $\frac{1}{2}$ in. at the end of the joint, using a slightly featheredged flame. As the joint begins

to melt, drop the rod into the puddle and begin the weld, being sure to secure full fusion and penetration.

Stainless-steel welding is different from any other type of welding in that the weld is made with as little puddling as possible. The less the metal is exposed to air, the better the weld will be. Two elements,

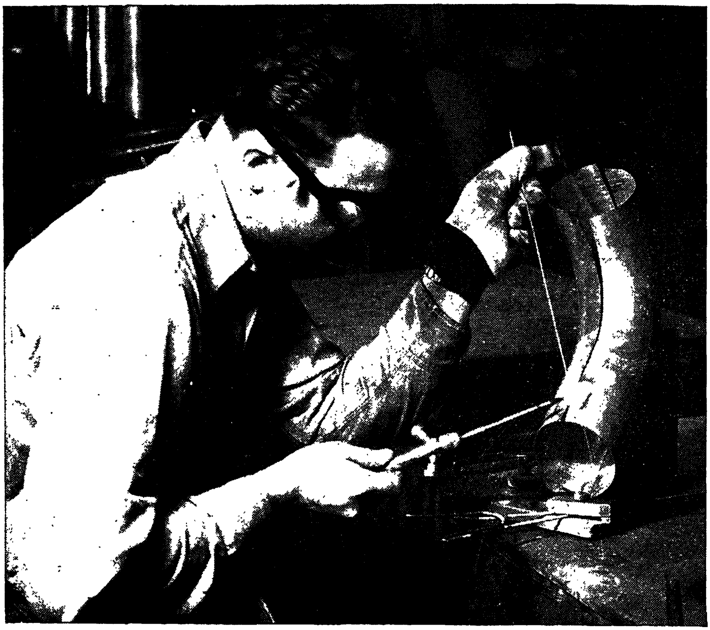


FIG. 101.—Stainless-steel welding on aircraft parts. (*Courtesy of Air Reduction Sales Co.*)

columbium and titanium, are present in the welding rod to replace these elements in the weld as they are burned out of the puddle during welding.

The end of the rod is kept in the puddle at all times. The envelope of flame over the puddle aids in preventing oxidation. The flux on the bottom of the joint covers the molten penetration bead and also prevents this effect.

In the actual welding the rod is pulled forward to the fore edge of the puddle but never out of the envelope of the flame. The torch swings forward on the rod, melting off a little, and then is drawn down into the puddle to secure full fusion and penetration. There is no side motion of the torch or rod. The flame never goes back through the deposited metal. Lock all stainless-steel welds (Fig. 101).

The surface of the correctly made weld will be fairly flat, with smooth, even ripples. The penetration bead will be rounded, with smooth ripples.

Test coupons from each plate (see Testing Weld Samples, page 230).

CHAPTER XI

BRAZING

A welder engaged in maintenance and repair work must have a thorough knowledge of brazing and bronze welding. Brazing is used not only in repair work but in sheet-metal work and in the manufacture of equipment in which the weld is subject to corrosion.

There is a difference between brazing and bronze welding. Bronze welding is a fusion process exactly like that of welding cast iron and aluminum. A bronze welding rod and brazing flux are used to fusion-weld brass and bronze. Copper may be fusion-welded, although it can be brazed successfully with less heat and distortion than would occur in fusion welding.

In the process of brazing the base metal is not melted. After the area to be brazed is heated sufficiently, flux is used to remove completely surface oxides and impurities. The bronze welding rod is then dipped in flux and melted over the surface to be brazed. The melting rod infiltrates into the cleansed surface of the base metal.

Brazing develops high strength. The strength of a brazed joint in cast iron has about five times the strength of the cast iron itself. Brazing is the only successful method of welding malleable iron. There are two brazing fluxes used on a brazing job, a low-heat and a medium-heat flux (Fig. 102). If the casting is very heavy, involving a great deal of heat, a third, a high-heat, flux is used.

A bronze welding rod containing manganese is the most suitable for high strength and quality (Fig. 103). The

procedure as outlined in the following will be applicable to all brazing jobs, whether large or small.

Use an old cast-iron cylinder head for a practice plate. Use a No. 4 welding tip, with the regulator pressures

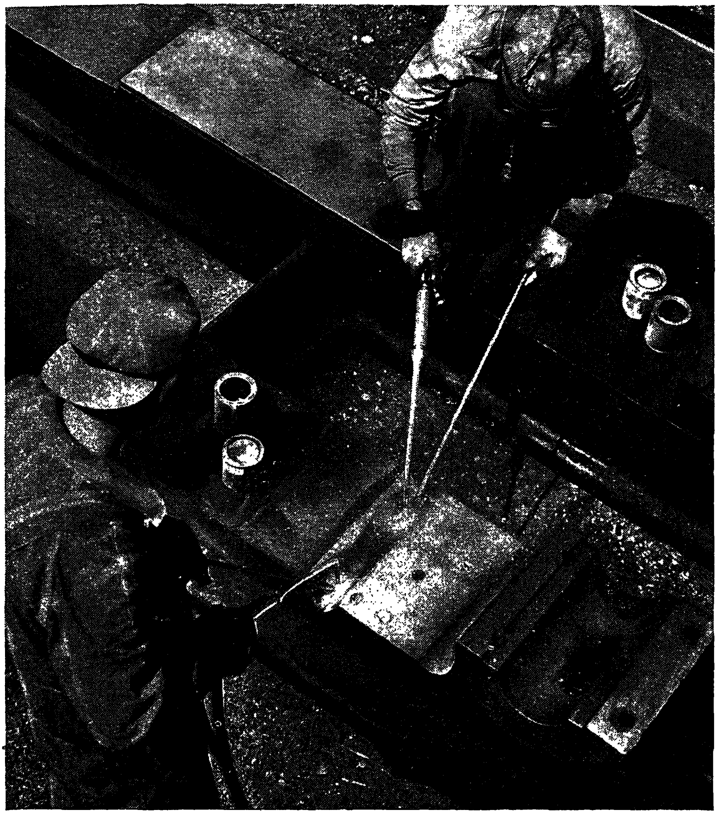


FIG. 102.—Bronze welding a 6-ton, cast-iron bed frame for an upsetting machine. (*Courtesy of Linde Air Products Co.*)

set at 10 lb. for the oxygen and 5 lb. for the acetylene. Vee out a crack on the side of the cylinder head. Use the veeing technique learned in cast-iron welding. This method leaves a roughened porous surface, ideal for

brazing. Always use either a torch or the electric welding process to vee out a crack preparatory to brazing. Never grind a surface to be brazed, for grinding smooths the surface of the metal and the bronze weld can only plaster to the surface of the parent metal, as it is unable to penetrate the metal.

Change to a No. 2 welding tip, and set the regulator pressures at 2 lb. each. Use a 1/8-in. manganese bronze

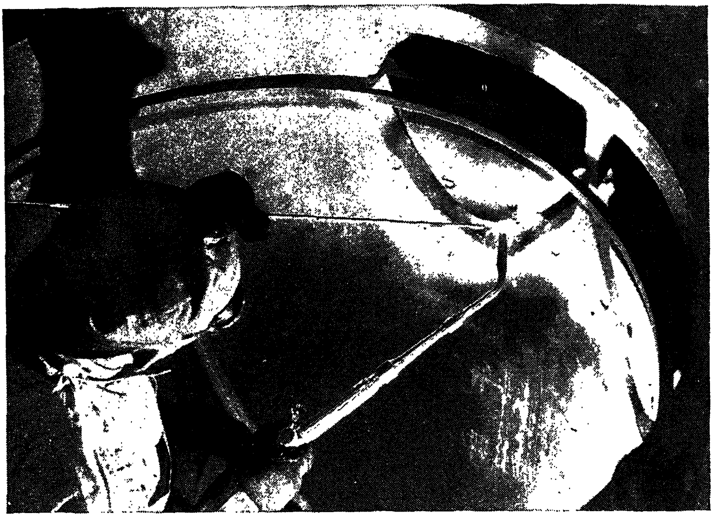


Fig. 103.—Bronze welded repair on a main cylinder in a cargo vessel. (*Courtesy of Linde Air Products Co.*)

welding rod and a can of low-heat brazing flux. Light and adjust the torch to a slightly oxidizing flame. Preheat the crack for about 1 in. along the joint until it becomes a dull red color. Do not heat an area outside the bevels. Heat the end of the rod, and dip it into the flux can. Hold the rod stationary, and the flux will adhere to it.

Wipe the rod along the preheated joint until the flux melts and spreads over the area to be brazed, removing

oxides and impurities. Dip the rod in the flux again, and melt a very small amount on the end of the crack. When the deposit strikes the base metal, it should flow out thinly over the heated surface, like hot butter.

If the deposit balls up or seems to roll, either the base metal is not hot enough or insufficient flux was used to clean the base metal thoroughly. If the deposit balls up, melt it away. Add more flux to the base metal, and heat until the deposit will flow like hot butter upon contact with the base metal.

Deposit a thin layer of bronze about $\frac{1}{16}$ in. thick over the entire surface of the area to be brazed. This is called the *tinning process*. Deposit only about $1\frac{1}{4}$ in. of weld at one time to avoid overheating. At the completion of each $1\frac{1}{4}$-in. pass, pull the welding flame out of the puddle and add more flux to the welding rod.

The secret of good low-heat brazing is not to overheat the base metal. When the torch flame is drawn away from the puddle, the red area directly in front of the puddle should disappear in 3 sec. The red area should never extend out of the bevels into the parent metal. If the casting is too hot, the deposit will fume and splutter and blue smoke will rise from the puddle.

Continue with the low-heat flux until the entire surface of the bevels or sides of the crack is thoroughly tinned. Be sure that good penetration is obtained through the joints and that the top edges of the joint are well tinned. Place the lid on the low-heat flux can, and set it aside. Always keep the lid on flux cans when they are not in use.

The first pass is very important. It is made with much lower heat than if the standard medium-heat flux were used, and this aids in preventing distortion. The low-heat flux makes a stronger bond with the base

metal than the average medium-heat flux. It will also bond rapidly with dirty or poor-grade cast iron.

The low-heat flux is used only to make the first pass on cast or malleable iron. It is never used to make the second pass or to weld brass or copper. If the casting is thin enough, one pass will fill the vee. Do not add a second pass.

Use the same welding tip and welding rod and the medium-heat brazing flux. The first pass was a tinning pass or brazing action. The second pass is actually bronze welding in that it is fused into the first pass but not through the first deposit into the parent metal.

Weld only for 1½ in. at a time, fusing well into the tinning pass. Do not carry a large puddle. If necessary, make several passes with the medium-heat flux. The weld should be very smooth, with closely spaced ripples and the edges feathered into the base metal. There must never be a thick or a rolled edge on a bronze weld. There will be a thin gold stain about ¼ in. wide on each side of the properly tinned weld where the tinning pass has soaked out into the base metal.

Test the bronze weld by melting away the deposit with a welding flame. If the weld has been well penetrated and bonded to the parent metal, it will be very difficult to remove the weld. The bronze will literally have to be burned out of the parent metal. If a good bond has not been obtained, the bronze weld will separate easily from the parent metal, leaving dark spots where there was poor bonding. You can make several tests in addition to the one mentioned in order to assure yourself that you have mastered brazing.

Braze pieces of 18-gauge black iron together. Cut out coupons, and test (see Testing Weld Samples, page 234). Braze a piece of ¼- by 2-in. mild-steel bar

about 6 in. in length to the thick part of a cylinder head. After the weld has cooled, knock the mild-steel piece from the casting. If the bronze weld is made correctly, the casting will give way around the bronze weld, leaving the mild-steel piece with a heavy footing of cast iron.

CHAPTER XII

TABLES. SAFETY RULES

Melting Points of Metals

Metal	Degrees Fahrenheit
Chromium	2940
Pure iron	2800
Mild steel	2690
Monel	2490
Cast iron	2050–2200
Copper	1980
Brass	1570–1900
Bronze	1300–1900
Aluminum	1200
Zinc	780
Lead	620
Babbitt	480
Tin	450

Time and Material Necessary for Cutting Steel

Thickness of metal, inches	Hand cutting, inches per minute	Gas consumption, cubic feet per minute	
		Oxygen	Acetylene
¼	21	1.5	0.16
½	18	1.9	0.20
1	14	2.7	0.24
3	8	4.4	0.34
5	5.3	6.9	0.45
8	3.9	9.4	0.59
12	1.9	13.3	0.88

Time and Material Necessary for Welding Steel

Thickness of metal, inches	Oxygen, cubic feet per hour	Acetylene, cubic feet per hour	Speed, feet per hour	Welding rod, pounds per foot
1/16	6.5	5.5	24	0.03
1/8	11.5	11.0	16	0.07
3/16	15.0	14.0	10	0.13
1/4	21.0	20.0	7 1/2	0.21
1/2	41.0	38.0	3 1/2	0.60
3/4	60.0	55.5	2	1.85
1	85.0	78.0	1 1/2	3.00

SAFETY RULES

1. Thoroughly clean lens before starting work. Change cover lens if necessary.
2. Check helmet for cracks or holes allowing light to seep through. A small piece of adhesive tape will block light until the helmet can be properly repaired.
3. Make sure that the colored lens is neither too light nor too dark; both conditions will produce eyestrain.
4. Great care must be exercised that the electrode does not come in contact with the work while the helmet is raised. Exposure to the arc flash will severely burn the eyes.
5. Always wear goggles or helmet when in the vicinity of another welder operating the arc.
6. Use a shield at all times when arc welding. This will protect others working in the vicinity.
7. Remember it is possible for the arc to burn the eyes even though you do not look directly at it.
8. Always use chipping goggles or a helmet having the extra lens on the inside when the window is raised. This precaution will enable you to chip and clean the scale from the weld without endangering the eyes.

9. If a particle of scale enters the eye, go at once to a competent first-aid man or physician. Under no circumstances allow amateurs to make an attempt to remove the particle. It is very seldom that a piece of embedded slag will leave the eye of its own accord.
10. If you receive a flash of the arc or have foreign material removed from the eyes, wash them with a boric acid solution or apply a few drops of 10 per cent Argyrol (this must be applied at not less than 4-hr. intervals). Cold witch-hazel compresses, renewed at short intervals, applied to the closed eyes afford the best method of relief for the inflamed condition. Eye burn is always very painful and lasting. The best course is to prevent burns rather than to try to cure them.
11. Do not leave welding rods on the floor. Severe injuries may result from a fall caused by stepping on rolling objects.
12. Never leave welded pieces on the bench without labeling them "hot." This precaution will prevent injury from burns to others working near.
13. Do not arc-weld with sleeves rolled or shirt collar open. Always use gloves. These precautions will not stamp you as a "sissy" but will prevent nasty burns. The rays radiated from the arc cause severe burns resembling aggravated cases of sunburn.
14. In the event of an arc burn, apply any good burn ointment and treat as any serious burn.
15. Cuffs should be removed from the legs of working garments, and pockets should have flaps. Sparks invariably fall into cuffs and open pockets.
16. Never carry matches in shirt pockets. Severe burns may result from a flying spark igniting the matches.

PRECAUTIONS IN WELDING GALVANIZED IRON

1. Galvanizing is best explained as a process whereby plain iron is dipped in a solution and retains a coat of the solution. In welding on iron that has been so treated, a gas, largely zinc oxide, is thrown off. This gas is highly injurious and causes violent illness when inhaled. As far as possible, weld in a well-ventilated place so that the fumes will be carried away.
2. Drinking milk frequently during a long period of galvanized work is beneficial, as the milk seems to absorb the poison. Drinking milk after the fumes have been absorbed and have caused illness is also beneficial.

PRECAUTIONS IN WELDING IN THE PRESENCE OF EXPLOSIVE FUMES

Gasoline tanks or cylinders containing gasoline may be successfully welded, but only by the welder who has the equipment and the ability to do the job. It will be necessary, at times, for you to weld or cut on cylinders, oil drums, gas tanks, or various grease containers.

A full tank of gasoline will only burn if ignited. An empty gasoline tank will explode violently when exposed to fire, owing to the gasoline vapors remaining in the tank. Gasoline fumes do not leave an empty tank. It is a known fact that tanks have blown up when cut into with a torch even though they had been empty for a year or more.

When welding or cutting near a gasoline tank, be sure the tank is full of gasoline. Keep a wet rag around the gas cap and any other connections to prevent escaping fumes igniting.

If it becomes necessary for the job-shop or field welder who is not equipped with steaming or carbon monoxide equipment to repair an empty gasoline tank, the tank must be filled with water before heat is applied. The water must remain in the tank while the work is being done. If it is not practical to fill the tank or cylinder with water, do not attempt to weld or cut on the vessel. A safe practice is to regard every tank or cylinder brought to you for repair as though it had contained gasoline.

Never heat or cut into barrels that have or have had oil, grease, or tar in them without first venting the barrels. The vent allows the fumes to escape before they reach a flash point and explode. Whenever it is necessary to heat or weld on transmission cases, crankcases, or any closed container, be sure the vents are open.

PART II

Arc Welding

CHAPTER XIII

THE WELDING MACHINE AND ITS CARE

There are two types of welding unit producing the necessary current for arc welding, the motor-generator type and the alternating-current (a.c.) type.

The motor-generator set is composed of an electric motor driven by a 440- or 220-volt circuit. The electric motor drives a generator, which develops the necessary current for welding. This is the direct-current (d.c.) welding unit. The electrically driven generator is used primarily in the shop or yards where electric power is readily available (Fig. 104). On construction jobs or field work where power is not accessible a gas engine is used to drive the generator (Fig. 105).

The stationary welding machine must have sufficient ventilation. It should be set at least 12 in. from the floor to keep dust from it. Wipe the armature clean, from time to time, to ensure full performance. Check the brushes frequently to be certain they work freely in the holders. Do not allow the brushes to wear short before replacing. Do not set the generator where chips, filings, or cuttings may fall upon the armature. If compressed air, not oxygen, is available, blow the dust from the unit frequently. Oil regularly according to the manufacturer's specifications.

The same basic care must be given the portable unit although the problem of dust, oil, and grease is greater with the stationary type of welding machine.

The a.c. welding set is a transformer. Thirty amperes at 440 volts flows in the primary and is delivered as 200

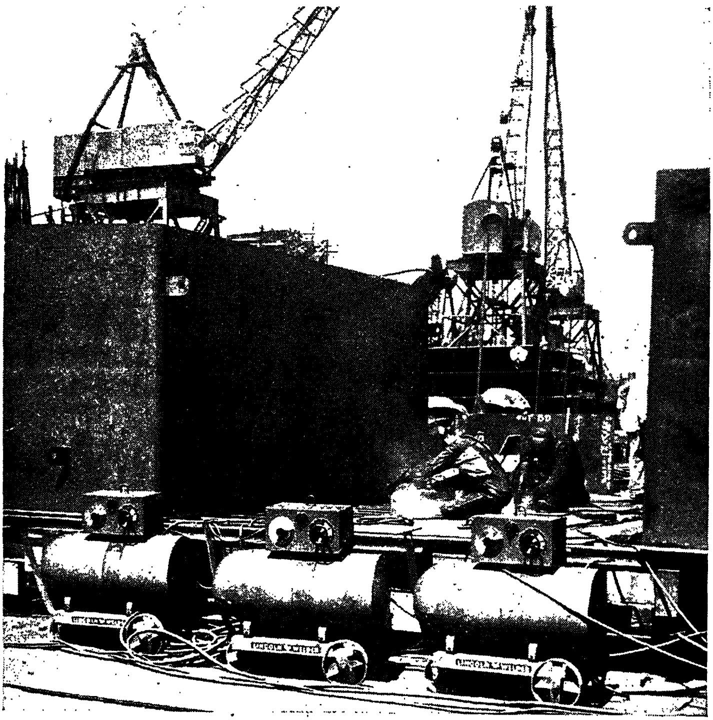


FIG. 104.—Electrically driven arc-welding generators at work in a west coast shipyard. (*Courtesy of Lincoln Electric Co.*)

amp. at 40 volts. This is the standard size welding unit although various manufacturers make welding sets of larger and smaller capacities (Fig. 106).

The principal advantages of an a.c. set are the low original cost, the low upkeep, the smoothness of the deposit, and the ability to weld into corners without arc

blow. The polarity cannot be reversed on an a.c. set since, by reason of its basic principles, it reverses itself approximately 120 times a second.

AMPERES AND VOLTS

In reference to the welding current the welder must think in terms of *amperes* and *volts*. To the welder,

FIG. 105.—Gas-driven arc welder mounted on the back of a truck to do portable work in the field. (*Courtesy of Lincoln Electric Co.*)

amperes represent heat and voltage represents force. In a dual-control machine, the amperage and voltage are separately controlled. In a single-control machine, the amperage is set by the control, and the voltage is automatically regulated.

The ability to control the amperage and voltage separately is an advantage in arc welding. For example,

if you are making a flat weld on ½-in. plate, using a 5/32-in. electrode, the heat adjustment would be about 160 amp. and 15 volts. With low voltage, much heat may be used on flat work. With high amperage and high voltage, the arc would dig too deeply into the plate. Making the weld in the vertical or overhead position

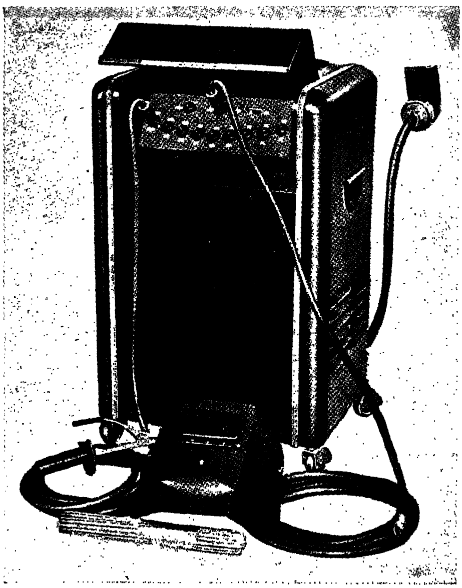


FIG. 106.—200-amp. a.c. arc welder. (*Al Rhodes photograph.*)

requires less heat than for the flat weld; but in order to drive the weld into the base plates and hold it there it is necessary to use more force, or voltage. Settings on the welding machine for making a weld on ½-in. plate in the overhead position with a 5/32-in. electrode would read 135 amp. and 22 volts. Raising or lowering the voltage only a few points makes a great difference in the depth of penetration.

POLARITY

In setting the current adjustments on the welding machine preparatory to making a weld, you must have the correct *polarity*. To the welder the polarity means the direction of the flow of the current. There are two forms of polarity, straight and reverse.

The current from a d.c. machine always flows in one direction, from the positive side to the negative. If the ground cable were fastened to the positive terminal on

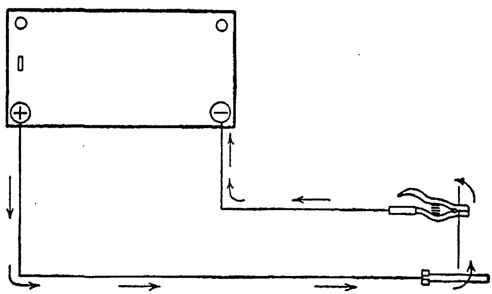


FIG. 107.—Straight polarity. Direction of flow of current when ground plate is on the positive side of the welding machine.

the machine and the lead cable were fastened to the negative terminal, the heat would flow from the welding machine through the ground cable to the work, through the electrode and holder into the lead cable and back to the machine (Fig. 107). This is straight polarity.

While it is possible to make good welds in the vertical and overhead positions with straight-polarity rods, it is difficult to do so. The straight-polarity rods are generally used for build-up work and for bridging poor fit ups. Very smooth, even welds of high quality are made with straight-polarity rods.

If the lead cable is fastened to the positive side of the welding machine and the ground cable to the negative

side, the result is reverse polarity (Fig. 108). The heat flows from the welding machine through the lead cable to the electrode holder, through the electrode to the ground plate, and through the ground cable to the welding machine. There is much more penetrating power in the reverse-polarity rods, and they may be used in any position.

In order to reverse polarity on certain types of welding machine the cables must be reversed on the terminals.

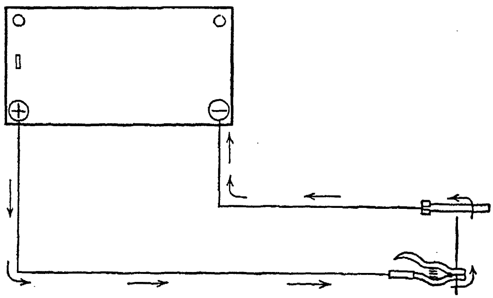


FIG. 108.—Reverse polarity. Direction of flow of current when the ground plate is on the negative side of the welding machine.

However, other types are equipped with a polarity switch, which controls polarity.

If for any reason you cannot determine the polarity on the arc-welding machine, select a reverse-polarity electrode and begin the weld. If the weld is made without difficulty, the machine is set on reverse polarity. If the arc flares, sputters, hisses, and throws off showers of sparks accompanied by clouds of smoke, the machine is set on straight polarity. A reverse-polarity welding rod will not weld with the machine set on straight polarity.

HEAT CONTROL

A chart giving the exact amount of amperes and volts to be used with certain sizes of electrodes and plates is

impractical because of the personal preferences and abilities of the individual welder. Current settings on some machines vary widely from those on others. Often, ammeters and voltmeters are damaged and fail to register.

The length of the welding cable affects the meter setting. There is a voltage drop as the length of the cable increases, and it may be desirable to change both the voltage setting and the ampere setting to secure additional voltage for the long cable. The safe practice is to set the welding heat so that the parent metal and the electrode melt and flow together, regardless of the position of the weld. Certain rod manufacturers in an attempt to aid the welder in selecting his welding current have compiled a list of heat ranges, which they print on each box of electrodes. These may be used as a general guide but are in no way conclusive.

In the succeeding lessons, approximate amperage and voltage settings are recommended. Since the length of the arc held will affect the voltage, always keep the end of the electrode within ⅛ in. of the plate during welding. The voltage must be set while the welding machine is being used. If the welder maintains a steady arc, a fairly accurate setting may be obtained.

CHAPTER XIV

THE ELECTRODE

The coated electrode is a bare rod with a coating of flux. The flux melts more slowly than the steel rod (Fig. 109), thus providing a shield for the arc. This shield steadies the arc, gives it directional force, and enables the welder to place the weld material exactly where he wishes. During the welding the flux melts and flows into the puddle, where it acts as a cleansing agent, carrying the oxides and impurities from the puddle to the outside surface. There it forms a heavy slag over the cooled portion of the weld.

As the flux melts and flows into the puddle, it forms a heavy inert gas around the arc and melting puddle excluding all oxygen (Fig. 109). This prevents the hot metal from absorbing oxygen. The slag forming immediately behind the puddle also keeps the hot metal from becoming oxidized. Since the weld is not oxidized, it has a high tensile strength and great ductility.

There are four classes of electrodes for welding mild steel: the bare electrode; the straight-polarity coated electrode, used primarily for flat welding, build-up work, and bridging poor fit ups; the reverse-polarity coated rod, which is used in all positions and has deep penetrating power; and the a.c. coated electrode, which has the same characteristics as the straight-polarity electrode.

The a.c. electrode and the straight-polarity electrode may be used on either polarity, but using them on

reverse polarity gives them slightly more penetration. The bare electrode is used only on straight polarity.

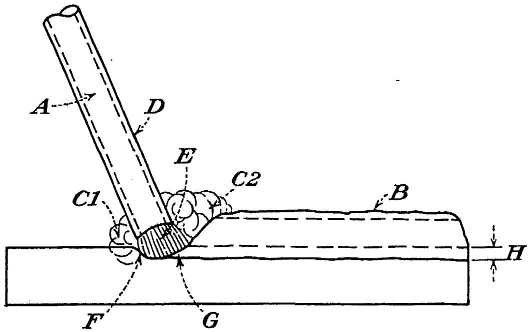


FIG. 109.—*A*. Steel rod or core melts faster than coating *D*. *B*. Scale or slag coating on weld deposit. *C*1, *C*2. Gas shield protecting arc stream and molten metal from oxidation. *D*. Coating on electrode. *E*. Arc stream. *F*. Crater. *G*. Weld puddle. *H*. Penetration of weld into plate.

The reverse-polarity rod is used only on reverse polarity to make a weld. It will not weld on an a.c. machine or on straight polarity.

CHAPTER XV

WEARING APPAREL. THE WELDING BOOTH AND WELDING BENCH

WEARING APPAREL

Serious burns to the welder's skin and damage to his clothing will result from exposure to the rays of the arc. The shower of sparks and particles of hot metal continually present during arc welding causes great discomfort and entails the danger of severe injury. Adequate protective clothing to fit any condition is available from reliable manufacturers (Fig. 110).

THE WELDING BOOTH

If the actual welding or practice welding is done in one location, a welding booth must be constructed to protect passers-by from exposure to the arc flash. The booth may be built of plywood or other light material. It should have a swinging door or a heavy curtain that will fall easily in place.

The booth may be 5 by 6 ft. inside. The top of the booth should be 6 ft. from the floor and uncovered. The sides should be 12 in. from the floor, to provide ventilation. There should be a suction vent above the booth to carry away all fumes and smoke (Fig. 111). The inside of the booth must be painted with lampblack to absorb all the light rays of the arc. Otherwise, the eyes may be burned from the reflections of the arc entering the rear of the helmet.

If there is a light fixture in the booth, it must be placed so that the hot sparks will not fall upon it and so that the light will shine on the welding plate. If

FIG. 110.—Arc welder's outfit consists of skullcap, flip-front helmet, full-length leather jacket, leather overalls, leather welding gloves, and chipping goggles.

possible, place the light so that it will not reflect in the helmet.

There must be hooks in the booth on which to hang the cables.

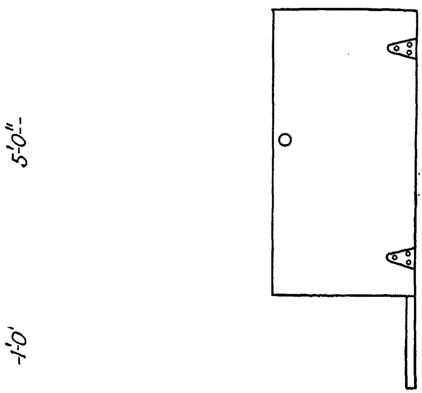


FIG. 111.—Arc booth and ventilator.

FIG. 112.—The shield around the weld keeps out wind and prevents bystanders from getting their eyes burned by a flash. (*Courtesy of Lincoln Electric Co.*)

Where a welding booth is not practical, as for portable work, a screen should be used to shield the arc weld (Fig. 112).

THE WELDING BENCH

A bench, or table, is necessary on which to line and tack the plates preparatory to welding. The top of the

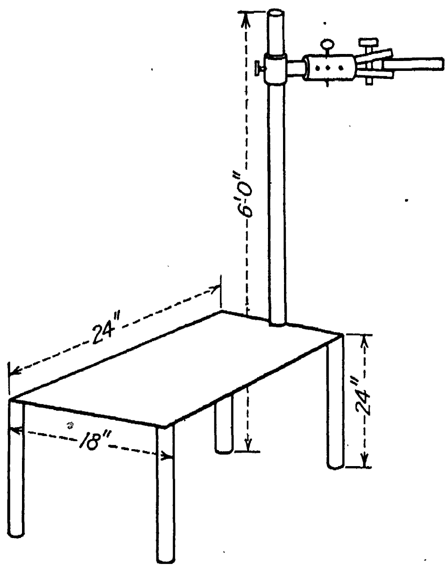


FIG. 113.—Welding table and plate holder.

welding table should be 18 by 24 in. and 24 in. from the floor. It may be of brick or steel. If the surface is of brick, it must be very smooth to permit accurate lining of the plates. If the top is of steel, do not weld or tack to it. Use the plateholder (Fig. 113) to support the welding plates. The ground cable should be bolted or welded to the table leg to ensure a perfect ground.

CHAPTER XVI

BEADING TECHNIQUE

Lesson 28

Striking the Arc and Running a Bead in the Flat Position

Select a scrap piece of 3/8-in. mild-steel plate, and place it on the welding bench. Use a 5/32-in. reverse-polarity electrode. Set the welding machine at approximately 135 amp. and 18 volts, with reverse polarity.

Inspect your helmet for dirty glasses or leaks. Seat yourself at the bench in a comfortable position, with the lead cable across the lap or over the shoulder to prevent drag on the electrode holder. Use the electrode holder in the right hand with the thumb on the handle side (Fig. 114), and support the holder or right hand with the left hand. Welding one-handed is not a sign of skill, and adds hours to the period of training. Sit directly in front of the practice plate, and work from left to right. In this position you can see the penetration of the puddle and at the same time can watch the fusion and finished surface of the weld.

Insert the bare end of the electrode in the holder. The weld will begin at the left end of the plate, if you are right-handed, and will progress to the extreme right edge. Hold the electrode over the plate so that it is directly in line with the line of travel and pointing into the weld at about a 30-deg. angle (Fig. 115). Drop the helmet over your face, and strike the arc.

There are two methods of striking the arc, the tapping and the scratching methods (Fig. 116*A* and *B*). Do

not strike the electrode heavily against the base plate, but touch it lightly. In the tapping method the electrode is struck lightly against the plate, lifted up to allow the arc to flare, and then moved ahead and down

Fig. 114.—Recommended welding position in making a weld in the flat position. (*Courtesy of Bob Kennedy, California Polytechnic Institute.*)

to the starting point of the weld. In the scratching method, the electrode is struck behind the starting point of the weld and then dragged forward, much as in striking a match, to the starting point of the weld, where the electrode is then held at the correct distance from the puddle.

If the electrode "freezes," or welds, to the plate, free it by rocking it back and forth. If this does not release it, carefully remove the tongs, or electrode holder, from the rod. When the rod has cooled, it may be broken from the plate.

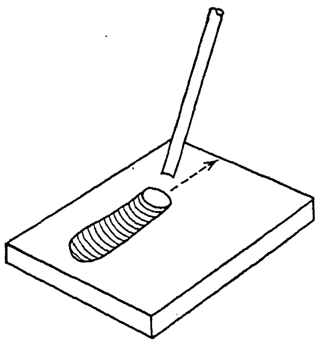


FIG. 115.—The electrode is held straight in the line of travel and pointing into the weld at a 30-deg. angle.

Pointing the electrode into the weld allows the arc to strike the base plate first and penetrate to the desired depth (Fig. 109). The weld metal will flow back from the crater, or arc puddle, and the slag, or scale, will wash through the puddle to the outside edge. The speed of forward travel regulates the size of the deposit.

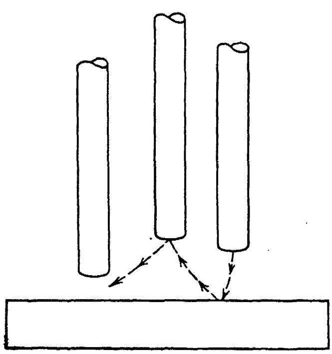


FIG. 116*A*.—The tapping method of striking the arc.

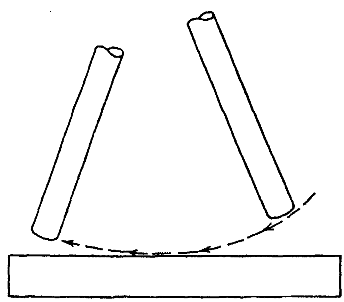


FIG. 116*B*.—The scratching method of striking the arc.

After striking the arc, keep the end of the electrode within ⅛ in. of the plate, and move steadily along the line of travel with no weaving or whipping motion. This is a single stringer bead.

Remember the rod is continually melting and must be constantly lowered into the puddle as the weld progresses. An arc of the correct length produces a steady crackling and frying sound. Too long an arc is indicated by a wavering action of the arc stream and a soft hissing sound, accompanied by explosive pops. If the arc is too short, the electrode will freeze to the plate.

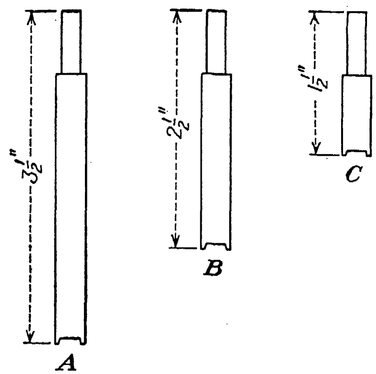


FIG. 117.—*A*. This length of stub is often discarded, yet it is actually 25 per cent of the electrode. *B*. This stub is shorter than stub *A*, yet it represents nearly 18 per cent of the electrode. *C*. 1½ in. is the maximum length for discarded stubs. They may be burned even shorter.

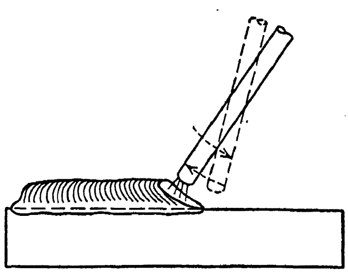


FIG. 118.—The whipping stroke.

Practice striking the arc until you can hold a steady arc and make five consecutive beads, each about 6 in. long, having a smooth, slightly rounded surface with close ripples. Watch the weld puddle closely to be sure that there is good penetration into the plate and that the edges of the puddle are fusing into it. Burn each electrode down to within 1½ in. of the holder before discarding (Fig. 117).

After you have finished these beads, practice running beads by using a whipping technique. The whipping

technique consists in advancing the weld by short back-and-forth movements of the electrode in the line of travel. No side motion is used. The whipping is done by moving the electrode forward about 5⁄16 in. ahead of the puddle, thus securing good penetration. Then the electrode is swung back into the puddle, held there long enough for the deposit to build up to the correct size, and then swung forward to secure further penetration (Fig. 118).

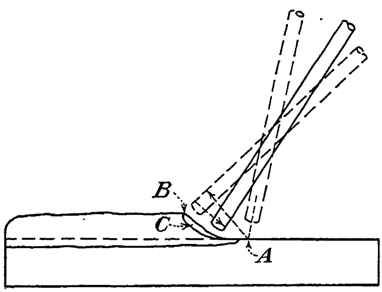


FIG. 119.—Strike the arc at point *A*, move quickly to point *B*. Hold the electrode still until the arc is fusing into the weld, then move slowly forward through puddle *C* on the first move of the whipping stroke. This gives perfect fusion and eliminates *cold lap*.

The regularity and steadiness of the whipping stroke determine the appearance of the finished bead, or weld. Do not swing the electrode too high in the puddle on the backstroke, for this will cause the weld metal to pile and be forced ahead onto the plate. Poor fusion and poor penetration will result.

Practice until you can make five consecutive beads each about 6 in. long, 3⁄8 in. wide, fairly flat across the top, well feathered into the plate, and with close even ripples.

If the weld is stopped during its progress, to change electrodes or to adjust the welding machine, attention must be given to starting the weld again. When restart-

ing the fillet weld, clean the flux from the deposited bead, with a chipping hammer, at least ½ in. back from the crater. Be sure that the eyes are protected from the flying pieces of slag. Strike the arc on the plate directly ahead of the crater, swing the arc back to the last high point on the weld (Fig. 119), hold it there until the puddle begins to melt, and then move slowly down the face of the puddle into the plate and continue the weld. This procedure gives perfect fusion in the joint and eliminates the possibility of plastering hot metal on cold metal, or "cold lap."

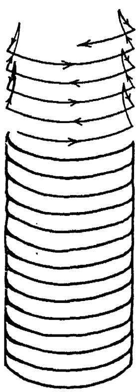


FIG. 120.—Square-U motion of the electrode.

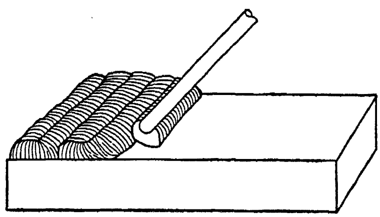


FIG. 121.—Keep the tops of the beads level. Weld one half into the previously deposited bead and one half into the base plate.

Now practice making beads by using a weaving motion. In making a weaving bead the arc is moved back and forth across the line of travel in a square U motion as the weld progresses (Fig. 120). The length of the side travel determines the width of the bead.

Keep the electrode pointing into the weld at about a 30-deg. angle and straight with the line of travel. Make a weld ¾ in. wide from the left of the plate to the extreme right edge. Advance the electrode one-half the thickness of the last deposited bead each time the electrode crosses the line of travel (Fig. 121), so that the weld will be made half in the last deposited bead and half into the plate.

Pause slightly at the end of each stroke to allow the weld metal to fuse into the plate. Travel faster when crossing the center of the weld. This area is constantly molten and, if the cross travel is too slow, will build up a high crown in the center of the weld. The finished weld should be ¾ in. wide, fairly flat, and with smooth, evenly spaced ripples.

LESSON 29

Making a Flat Fillet Weld in Three Passes

Select two pieces of ⅜-in. mild-steel plate about 6 by 8 in. Place one plate flat on the bench. Stand the

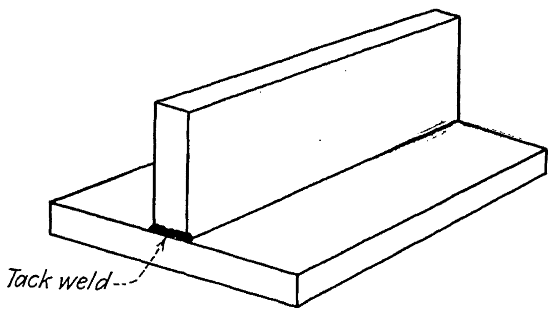


FIG. 122.—Vertical plate placed at right angles to the base plate.

other plate on edge on the flat plate about 1½ in. from one side (Fig. 122).

Set the welding current at 140 amp. and 15 volts, with reverse polarity. Use a 5/32-in. reverse-polarity electrode. Adjust your helmet, and tack the two plates together at each end. This is the horizontal, or, as it is commonly known, the *flat fillet weld.*

This weld is to be completed in three passes (Fig. 123). Start the weld at the left end of the fillet, and carry it out to the extreme right end of the joint.

The flat fillet can be made by moving the electrode steadily along the line of travel, without weaving or whipping. However, since it is not practical to use such a technique in any other position than the flat, use the whipping motion to make the flat fillet.

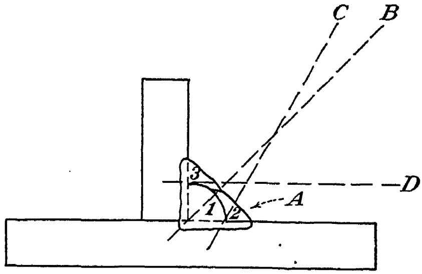


FIG. 123.—Three-pass fillet weld. 1, 2, and 3 indicate the order of deposited beads. *A*. Fairly flat surface of the finished weld. *B*, *C*, and *D* are positions of the electrode.

There are several problems that will be encountered in making the first pass. The bottom plate has a greater surface under the weld than the vertical plate and, consequently, will melt more slowly than the latter. The top edge of the weld along the vertical plate will

FIG. 124.—End view of a flat fillet weld. *A*. Small area actually welded. *B*. Undercut. *C*. Poorly fused rolled edge.

have a tendency to melt and run down on the bottom plate, forming a heavy rolled edge and leaving an undercut, or thin edge, along the upper edge of the weld (Fig. 124).

There are four points that must be closely watched in making a fillet weld. The metal must be well fused into the joint or throat of the fillet. The weld must be feathered into the bottom plate. There must be no undercut edge along the top of the weld, and the face of the weld must be fairly flat or slightly concave (Fig. 123). There should be no channel between the second and third beads.

Hold the rod at a 45-deg. angle between the plates and pointing into the weld at a 30-deg. angle. Strike

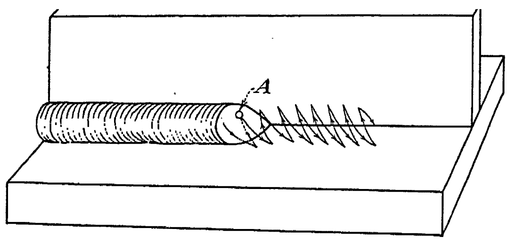


FIG. 125.

the arc at the extreme left end of the joint. Hold the electrode still while the arc melts into the joint and builds up the deposit to the desired size. Move forward along the joint, fusing well into the plates. Use the whipping stroke, but vary the direction of travel of the electrode. Instead of moving straight forward and back in the line of travel, move the electrode out on the bottom plate on the forward stroke and across the center of the joint and up against the vertical plate on the backstroke. Hold a very short arc against the vertical plate, and pause briefly at the top of the back swing to allow the deposit to fill in at the top edge of the weld (Fig. 125).

Before the puddle becomes too fluid and begins to run down, move forward and out again, then back. The electrode moving out and forward on the bottom plate

draws the deposit along, fusing it deeply into the plate. This action leaves the deposit feathered into the bottom plate along the lower edge. Moving back across the joint at every stroke keeps the puddle flowing ahead into the joint. Swinging the electrode higher on the vertical plate on the backstroke pins the weld deposit to the vertical plate. If an arc of the correct length, in this case a very short one, is held, the weld deposit will creep up the plate above the rod (Fig. 125). Therefore, in order to avoid an undercut, do not raise the electrode as far as you wish the deposit to go. Keep the point of the electrode just ahead of the back edge of the puddle so that the latter is being driven in and back.

This stroke is not a weaving bead, but a whipping stroke that runs slightly at an angle from the line of travel, rather than directly with it. This first bead should be $\frac{5}{16}$ in. wide across the top, with a slightly rounding surface.

Chip and brush the first bead thoroughly before making the second pass.

Raise the electrode past the 45-deg. angle until it stands at about a 60-deg. angle from the joint (Fig. 123). Keep the electrode pointing into the weld at a 30-deg. angle. Since the plates are hot from the heat of the first pass, the forward travel of the second pass will be faster. The purpose of the second pass is to weld the first pass and the base plate together. Cover three-fourths of the first pass and into the base plate for $\frac{1}{8}$ in. with the second pass (Fig. 123). Use the same whipping stroke as on the first pass, drawing the weld ahead along the bottom edge to feather it into the plate and swinging back across the joint of the first pass and the plate to a point covering three-fourths of the first bead. Keep the point of the electrode just ahead of the back of the puddle

so that the latter is being driven back and up. If the electrode is swung too far back into the puddle, it will drive the molten metal ahead, causing poor penetration and fusion.

FIG. 126.—Making the third pass on a three-pass fillet. Note the position of hands and electrode. (*Courtesy of Bob Kennedy, California Polytechnic Institute.*)

Carry each bead out to the end of the plate. If the plate cuts away at the edge, draw the arc quickly from the puddle, and as the latter begins to solidify hold a very short arc and deposit more metal. Continue until the weld is built up completely to the edge of the plate. The surface of the second pass must be flat across the

face and feathered into both edges. If a stroke of the same length is taken each time, the ripples will be evenly spaced.

Chip and brush the second pass thoroughly before making the third pass. The third pass will be smaller than the two previous beads. The forward travel of the third bead is faster than that of the other two because of the mounting heat in the plates.

Hold the electrode level with the bottom plate and pointing into the weld at a 30-deg. angle (Fig. 126). Advance the electrode with the same swinging, whipping technique as on the previous beads. Hold a short arc

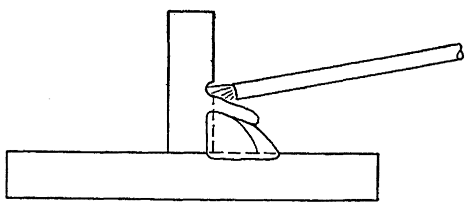


FIG. 127.—Undercut resulting from long arc held against vertical plate.

against the vertical plate on the back swing. An undercut occurs when too long an arc is held, for the latter digs in and flows down, leaving a cut edge (Fig. 127).

Keep the end of the electrode just ahead of the back of the puddle in order to drive the weld back and up. On the forward travel, bring the bottom edge of the bead just to the center of the joint. Be certain that the third bead fuses well into the joint between the previous beads and the plate. The second bead covers part of the first bead, and the third bead comes down over the second pass. There is only one clean, solid weld in the joint (Fig. 128).

On this pass as well as on the others, be sure that the puddle is flowing ahead cleanly into the plates and that

all dirt scale and oxides are flowing to the back of the puddle.

Practice making the flat fillet weld from right to left as well as from left to right. Make at least three consecutive fillet welds with no undercuts, overlaps, or channels between the beads, before proceeding to the next lesson.

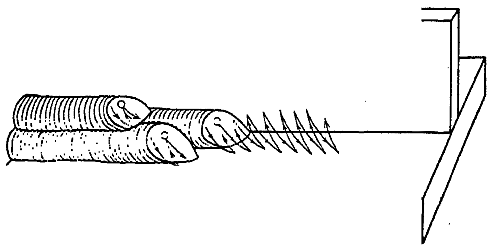


FIG. 128.—Motion of electrode on three-pass fillet weld.

LESSON 30

Making a Flat Fillet Weld in One Pass

The technique of making the single-pass flat fillet weld varies from that for the three-pass flat fillet only in the length of the stroke because of the larger electrode being used.

Line and tack two $\frac{3}{8}$-in. mild-steel plates in a flat fillet. Use a $\frac{3}{16}$-in. reverse-polarity electrode. Set the welding machine at approximately 160 amp. and 18 volts, with reverse polarity.

Check your helmet for bad lenses or leaks. Hold the electrode at a 30-deg. angle from the bottom plate and pointing into the weld at a 30-deg. angle (Fig. 129). Strike the arc at the extreme left end of the plates. Hold the electrode still until the arc is flowing into the plates and the deposit is built up to the desired size. Move forward, using a side whipping motion. Draw

the bottom edge of the weld along on the forward stroke, fusing well into the plates. Then swing across the joint and up against the vertical plate. Hold a short arc against the vertical plate until the weld metal climbs the latter at least 1/8 in. above the electrode. Then move forward, repeating the process.

If the electrode is drawn ahead too fast, a gas pocket may appear in the back of the weld directly behind the puddle. Move the electrode quickly back to that spot. Fill in the pocket, move forward through the puddle,

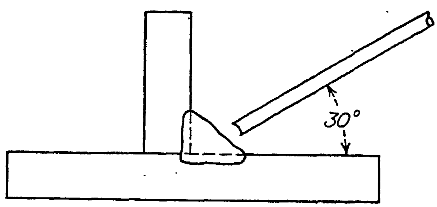


FIG. 129.—Position of electrode on single-pass flat fillet weld.

and resume the weld. If an undercut shows along the weld as it is made, swing the electrode back to that spot and, holding a short arc, fill in the cut and move ahead. By placing yourself in a position to see ahead and behind the puddle at all times, you may note these faulty conditions as soon as they occur and correct them instantly.

Always carry the weld to the extreme edge of the plates. The finished weld should be 1/2 in. across the face, fairly flat, equally distributed across the line of travel, and with regular ripples. Make at least three consecutive plates before proceeding to the next lesson.

If the flat fillet is to be made with the straight-polarity electrode, follow the same technique for the movements of the electrode. The amperage setting on the welding machine must be higher with the straight polarity.

Watch the puddle closely as the weld is made. The flux, or coating, on a straight-polarity electrode is heavier than on the reverse-polarity electrode and has a tendency to crawl forward around the puddle, partly hiding the puddle from view. The heavier flux gives the impression that a much larger deposit is being made than is actually the case.

Lesson 31

Making a Vertical Fillet Weld in Three Passes

Line and tack two pieces of 3/8-in. mild-steel plate 6 by 8 in. to form a fillet weld. Stand the fillet plates on end. The weld is to be made by progressing from the bottom of the plate to the top edge.

Use a 5/32-in. reverse-polarity electrode. Set the welding machine at approximately 130 amp. and 20 volts. The lower amperage and increased voltage reduce the heat in the joint and increase the directional force of the arc so that the weld metal is driven into the joint and held there.

Several conditions that will impede the making of the vertical fillet weld must be recognized. The flat plate, having a greater surface, will require more heat than the plate that is on edge, for an edge will heat much faster than a flat surface. The first bead in the vertical fillet weld will have a tendency to bridge the joint instead of fusing into it. The deposit will tend to grow high and narrow, as the weld progresses, leaving an undercut along both edges. While it is present in all fillet welds, arc blow, or magnetic blow, will cause most trouble in the vertical fillet weld. Theoretically, arc blow is caused by the flow of the direct current setting up a magnetic field in the joint of the fillet weld.

When this occurs, the arc becomes uneven and erratic. The deposit refuses to weld into the joint and sticks first to one plate and then to the other. This condition is not encountered with an a.c. welding set.

FIG. 130.—Making a three-pass vertical fillet weld. Note welder's position, left elbow resting on left knee, holder in a comfortable position, electrode pointing straight into the weld. (*Courtesy of Bob Kennedy, California Polytechnic Institute.*)

All these conditions may be overcome if the correct technique is used. Place yourself at the welding bench in a comfortable position (Fig. 130). Inspect your helmet. Sit in such a position that the electrode is pointing, not directly into the joint, but into the flat

plate (Fig. 131). Point the electrode straight into the puddle (Fig. 132). Start the weld at the bottom of the joint. Hold the electrode still, with a short arc, until

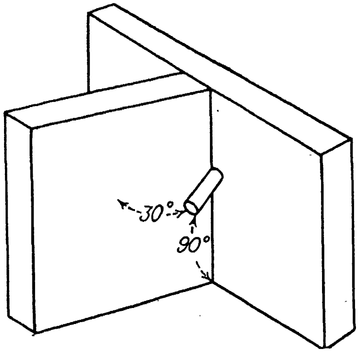


FIG. 131.—In making a vertical fillet weld point the electrode toward the flat plate rather than directly into the joint.

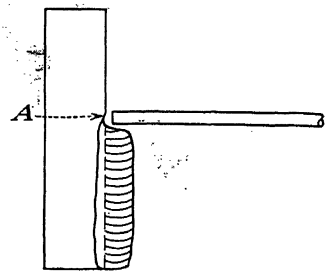


FIG. 132.—In making a vertical weld point the electrode directly into the weld. *A*. Throat of weld, or the fore edge of the puddle.

the arc is fusing well into the plates and the deposit is built up to the desired size. Move forward, using an inverted T motion (Fig. 133). It is necessary in making a vertical fillet weld continually to pull the electrode out of the weld to allow the puddle to begin to solidify so that it will not run over (Fig. 134).

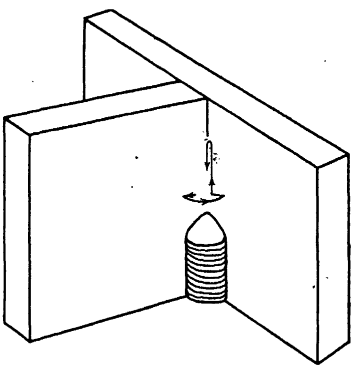


FIG. 133.—Movement of electrode in making a vertical fillet weld.

Do not advance the electrode too far ahead on the plates, for this action will deposit globules of metal along the line of travel that will later interfere with the making of the weld. At no time should the forward travel exceed ⅜ in.

On the leg of the inverted T, the arc is swung up along the flat plate for about ⅜ in., preheating the flat plate to bring it to the same heat as the edge plate. Do not move the electrode against the edge plate on the up-and-down travel. Bring the electrode down in the puddle, holding a short arc against the junction of the fore edge of the puddle and the plates (Fig. 132). Do

FIG. 134.—Vertical fillet weld.

not allow the electrode to come to the back edge of the puddle, for this would cause the puddle to run over.

As the short arc is held in the puddle, move the electrode from side to side to form the crossbar of the inverted T. Fuse well into both plates. This is the only time during welding of this first bead that the arc is moved against the edge plate. The purpose of the side movement, which does not constitute a weaving

bead, is slightly to flatten the crown of the bead and fuse its edges into each plate.

As soon as the deposit is brought to the correct size, swing the electrode out of the puddle and ahead on the leg of the inverted T. Do not move the electrode ahead with a semicircular motion. When the crossbar of the T is made, bring the electrode back to the joint before advancing. The electrode is pulled slightly away from the plates on its forward travel (Fig. 135) to avoid melting into the plate.

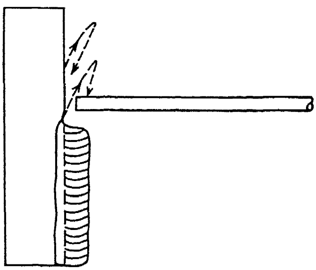


FIG. 135.—Position of electrode in up and down motion in making a vertical fillet weld.

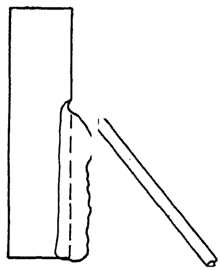


FIG. 136.—Do not point the electrode up into the puddle in making a vertical weld.

Drive the penetration into the flat plate and into and under the edge plate. There should be a crater 1/16 in. deep in the fore edge of the puddle at all times. If this crater and penetration are maintained, if the electrode is held straight into the puddle at all times, if the forward travel does not exceed 3/8 in., and if the correct amount of voltage is used, there will be no condition known as *arc blow*.

As the weld nears the top, the plates will become very hot. Use the same stroke and technique at all times. Increase the speed of the stroke to compensate for the rapid melting of the plates. Do not point the electrode up into the weld (Fig. 136). The electrode will arc

against the back of the puddle first, since the arc is a short circuit. This will cause the puddle to run over.

The correctly made weld is about $5/16$ in. across the face, with a slightly oval crown, the edges of the weld well fused into the plates, and the ripples of the weld very smooth and close together.

Chip and brush the first bead thoroughly before adding the second pass. Make the second bead on the right side of the first pass and the third bead on the left side of the first pass. Use a right-hand J motion on the second bead (Fig. 137).

Strike the arc at the bottom of the plates. Build up the puddle to the correct size, and swing the electrode forward out of it and at an angle across the line of travel just past the center of the first bead (Fig. 137). Swing the arc down into the puddle with a J motion. Be sure that the arc penetrates well into the junction of the plates and first bead. Carrying the arc across the line of travel and down into the side plate flattens the top surface of the weld and fuses it into the side plate.

Do not attempt to deposit as much metal on the second and third pass as on the first. Do not swing the electrode up at the completion of the lower end of the J motion (Fig. 138). This will cause the metal to roll down, leaving a thick edge and possibly an undercut. Use a regular stroke, but move ahead fast enough to keep the deposit fairly flat.

Chip and brush the weld thoroughly before adding the third bead.

The third bead is made with a left-hand J motion. Strike the arc at the bottom of the plate. Hold the electrode still until the puddle is the correct size. Then move the electrode forward across the line of travel until it just crosses the edge of the second bead, then

down into the puddle and into the side plate (Fig. 137). Continue the weld to the top of the plate. Keep the point of the puddle fusing well into the junction of the first bead and plate.

The first bead progresses straight up the center of the plates. The second bead extends just past the

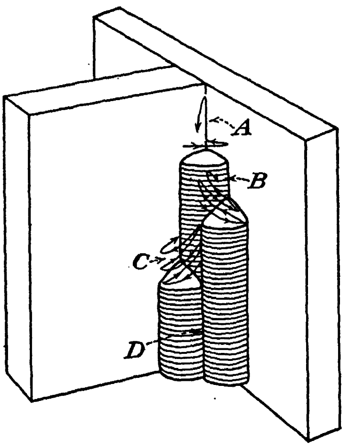


FIG. 137.—Vertical fillet weld. *A.* Inverted T motion. *B.* Travel of electrode in making a right-hand J motion. *C.* Travel of the electrode making left-hand J motion. *D.* The joint between the second and third bead is made in the center of the fillet weld.

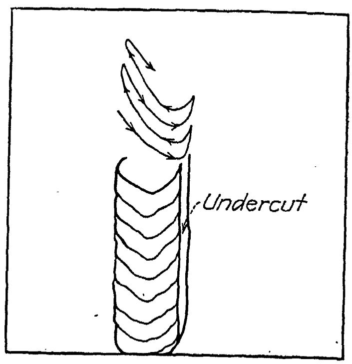


FIG. 138.—In making a vertical weld do not swing the electrode up at the completion of the down stroke on the J motion.

center of the first bead and into the side plate. The third bead extends just past the edge of the second bead and into the side plate. The junction of the two top beads should be directly in the center of the weld (Fig. 137). The surface of the weld is very flat and feathered into the plate. The ripples of the weld are smooth, very close together, and at right angles to the line of travel.

This is a difficult weld. You must be able to make at least three consecutive plates before proceeding to another lesson.

Lesson 32

Making a Vertical Fillet Weld in One Pass

Line and tack two 3/8-in. mild-steel plates to form a fillet weld. Place the tacked plates in a vertical position. Use a 3/16-in. reverse-polarity electrode. Set the current on the welding machine at approximately 145 amp. and 20 volts, with reverse polarity. This weld is made with the same technique as the first bead on the three-pass fillet weld except that the deposit in the single-pass weld must be about 5/8 in. across the face.

Use the inverted T technique. The length of the side strokes in the puddle, or of the crossbar of the T, determines the width of the puddle. Keep a crater approximately 1/8 in. deep directly in front of the puddle. Be certain that the up-and-down travel of the electrode, or the leg of the inverted T, is only 3/8 in. long and is made on the flat plate. Weld into the edge plate only when the electrode is in the puddle.

The weld should be about 5/8 in. wide, with a slightly rounding surface, the edges of the weld feathered into the plates, and the ripples evenly spaced and very close together. Make at least three single-pass vertical fillet welds before proceeding to another lesson.

Lesson 33

Making a Single-pass Weaving-bead Vertical Fillet

Line and tack together in the form of a fillet weld two 3/8-in. mild-steel plates, about 6 by 8 in. in size. Use a

$\frac{3}{16}$-in. reverse-polarity electrode. Set the current on the welding machine at 145 amp. and 20 volts.

Strike the arc at the bottom of the plate, keeping the electrode pointing straight into the weld. Build up a puddle. Move forward about $\frac{3}{8}$ in. directly up the line of travel, fusing into the plates. Pull the electrode down and along the plate on the left side of the joint. Swing the point of the electrode against the plate as the rod is drawn down. Pause at the end of the stroke, and then move straight across the line of travel to the opposite plate, pointing the end of the electrode against the plate on that side. Pause briefly, and then move forward into the point of the puddle and up the center of the joint (Fig. 139).

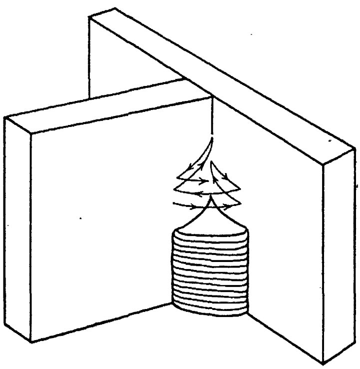


FIG. 139.—Vertical fillet made with a single-pass weaving bead.

When the electrode reaches the end of the forward travel, draw it back over the right side of the weld. Pausing briefly at the end of the stroke, move swiftly across the back of the weld to the left side. Pause briefly; then advance the electrode along the left side of the weld into the point of the puddle and up into the center of the joint. Continue until the weld is finished at the top of the plate.

The brief pause at the end of each side stroke fills in the edges of the weld, giving good fusion and preventing undercuts. Traveling rapidly across the back of the puddle prevents the weld being high and round. The surface of the weld must be very flat, with ripples closely spaced and uniform in shape (Fig. 139). On each cross

stroke, at the back of the puddle, advance the electrode one-half the thickness of the last deposit made by the electrode.

Make at least three consecutive plates before proceeding to another lesson.

In construction work another method is often used to make the vertical fillet weld. In this method the weld is made with two beads, one stringer bead run from the top of the plate down the joint to the bottom of the plate (Fig. 140) and a weaving bead, covering the stringer bead, made from the bottom of the plates to the top. The downhill stringer bead, made with a 3/16-in. reverse-polarity electrode, uses approximately 170 amp. and 25 volts. A slight U motion is used as the electrode is pulled down the joint. It is necessary to hold a very short arc, and the joint must be as clean as possible, to allow the deposit to fuse into the joint.

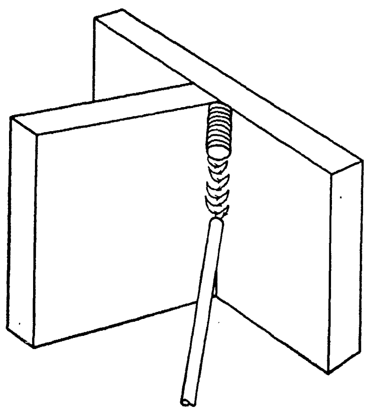


FIG. 140.—Vertical fillet weld, downhill welding.

The deposit made in this way is thin and is used primarily as a sealing bead. It is well to become familiar with this method before leaving the vertical fillet weld.

LESSON 34

Making an Overhead Fillet Weld in Three Passes

Line and tack two 3/8-in. mild-steel plates, 6 by 8 in., in the form of a fillet weld. Support the tacked plates in a plateholder, or tack-weld them to a vertical pipe

fastened to the welding bench. The plates should be placed at eye level. Suspend the plates so that one plate is vertical and the flat plate is in the overhead position (Fig. 141).

The overhead fillet is made with the same technique as the flat fillet. The first bead welds the two plates together at the joint, the second bead welds the first bead to the vertical plate, and the third bead welds the first bead to the overhead plate (Fig. 142). The two top beads meet exactly in the center of the joint.

FIG. 141.—Making a three-pass overhead fillet weld. Note position of right hand holding electrode holder, with the left hand supporting the right hand.

Use a 5/32-in. reverse-polarity electrode. Set the current at approximately 130 amp. and 20 volts. Hold the electrode holder so that the handle is on the thumb side. Then, without changing the position of the holder in your hand, twist the wrist so that the back of the knuckles is up as the electrode points into the plate (Fig. 141). Thus, the sparks and hot particles of metal will not lodge on the back of the glove. The electrode must point into the weld at a 30-deg. angle and at a 30-deg. angle from the vertical plate (Figs. 143 and 144).

Support the right hand with the left to steady the electrode. Loop the lead cable over the shoulder to prevent drag on the electrode holder. Do not stand directly in front of the weld as it is made. Stand a little

to the right (Fig. 141), for this enables you to see the weld and to be out of the direct shower of sparks from the puddle.

To overcome the effects of gravitational pull make a conscious effort to deposit 70 per cent of the first bead

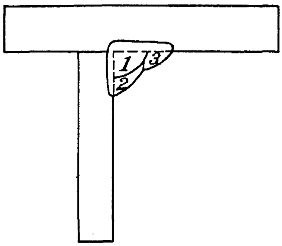


FIG. 142.—Overhead fillet weld. 1, 2, and 3 indicate the order of the deposits.

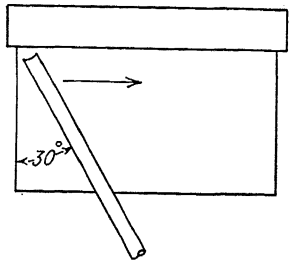


FIG. 143.—Overhead fillet weld. The electrode points into the weld at a 30-deg. angle at all times.

on the top plate and 30 per cent on the vertical plate. The deposit will then be evenly distributed across the joint.

Strike the arc against the extreme left edge of the plate, and hold the electrode still, pointing into the upper plate. As the plates begin to melt, move the electrode down across the line of travel into the vertical plate and slightly forward. Move the electrode across the line of travel, traveling slowly enough to ensure the arc fusing well into the joint. Move the electrode across the line of travel into the top plate, or flat plate; then pull the electrode out onto the top plate to the desired width. Move at a slight angle across the line of travel into the vertical plate and slightly forward (Fig. 145).

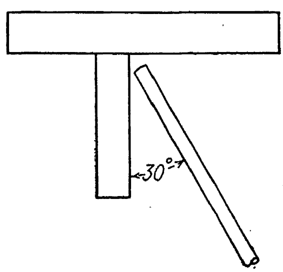


FIG. 144.—Overhead fillet weld.

Pause briefly at the top of the backstroke, holding a short arc against the upper plate in order to deposit enough metal to keep the weld to the correct size and prevent undercuts. On the forward stroke, move faster than on the return stroke. This is not a weaving technique but a whipping technique, running at an angle across the line of travel instead of directly with it. On both flat and overhead fillet welds this technique is designed to lift the deposit higher on the backstroke to

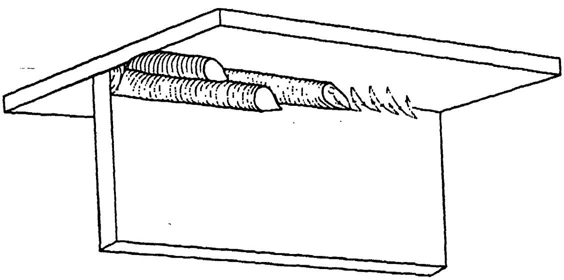


FIG. 145.—Overhead fillet weld in three passes.

prevent undercuts and to thin the edge of the weld on the forward stroke.

Fill in any gas pockets or undercuts as they occur. Be sure that the puddle is flowing evenly into the joint. Carry the weld out to the extreme right edge of the plates. The deposit should be 5⁄16 in. wide, slightly rounding on top, with no undercuts or rolled bottom edge, and having the surface of the bead smooth with very close ripples. Chip and brush the first bead thoroughly before adding the second pass.

The same technique and procedure are used to make the second pass on the overhead fillet as for the flat fillet. Use the same whipping technique, running at a slight angle across the line of travel (Fig. 125). Keep the electrode at a 30-deg. angle from the vertical plate

and pointing into the weld at 30 deg. Cover three-fourths of the first bead on the backstroke, and fuse well into the vertical plate along the edge of the first pass on the forward stroke.

Move faster on the second pass than on the first because of the increased heat in the plates and the fact that less metal is deposited on the second pass. Use the correct stopping and starting technique (page 154) on these beads to ensure perfect joints and maintain a smooth bead.

Chip and brush the second bead thoroughly before adding the third bead. Move forward faster on the third bead because of the growing heat in the plates and the decreased size of the deposit. Use the same whipping technique as before.

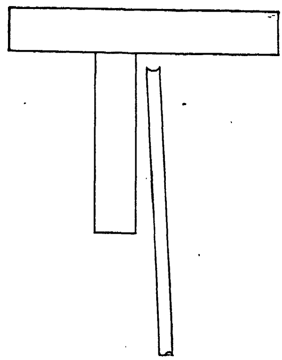


Fig. 146.—Overhead fillet weld showing position of electrode.

Point the electrode into the weld at a 30-deg. angle and as nearly parallel with the vertical plate as possible (Fig. 146). Strike the arc. Hold the electrode stationary to build up the deposit to the correct size, and then move forward at a slight angle into the weld.

As the electrode is moved back across the line of travel to the upper plate, hold a very short arc against the upper plate. Pause briefly at the top of the backstroke to allow the deposit to build up to the desired size and to prevent undercuts. Fuse well into the junction of the first bead and top plate.

The finished weld should be fairly flat across the face, with the second and third bead meeting exactly in the center of the joint. There must be no undercuts or

sagging edges. The ripples of the weld will be very close together.

Practice making this plate by running the beads from left to right and then from right to left. Make at least three consecutive overhead fillet welds with the necessary qualifications before proceeding to another lesson.

Lesson 35

Making an Overhead Fillet Weld in One Pass

Line and tack two $\frac{3}{8}$-in. mild-steel plates in the form of a fillet weld. Suspend these plates in the overhead position. Use a $\frac{3}{16}$-in. reverse-polarity electrode. Set the welding machine at approximately 145 amp. and 22 volts, with reverse polarity.

A new technique is used to make the single-pass overhead fillet weld. This does exactly what the other techniques were designed to do on their particular plates. It enables the welder to place the weld where it is needed, prevents undercuts and rolled edges, and at the same time obtains full fusion and penetration.

In making this weld, observe the usual precautions in avoiding the shower of sparks, maintaining full view of the weld as it progresses, and avoiding drag on the electrode holder.

Keep the electrode parallel with the vertical plate and pointing into the weld at a 30-deg. angle. Strike the arc against the end of the flat plate just above the joint. Hold the electrode still until the arc is fusing well into the plates.

It is important on the overhead fillet weld to put 70 per cent of the weld deposit on the upper plate and 30 per cent on the vertical plate. This overcomes the gravitational pull and leaves an evenly distributed weld across the joint.

In Fig. 147, point *A* marks the beginning of the stroke after the puddle has been started. The electrode progresses out and ahead for about ⅝ in., welding into the upper, or flat, plate to the required width, and dips downward and reverses itself, coming back just under the first pass, which plainly shows the method of not leaving an undercut. The electrode then swings up in a short V, level with the top of the first pass, and comes down across the face of the puddle in a J motion. This action welds into the vertical plate and, by moving the electrode slightly ahead at the bottom of the stroke,

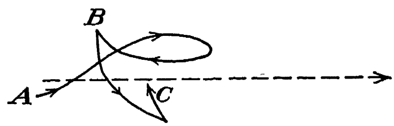


FIG. 147.—Movement of electrode on single-pass overhead fillet weld.

draws the puddle with it, having a tendency to flatten and preventing rolling or sagging.

On the next stroke the end of the electrode is thrust deep into the throat of the fillet just ahead of the puddle, is held there long enough to ensure full penetration, and then is carried up to the top of the weld puddle and ahead as before. This is a continuous motion from start to finish. The puddle remains molten at all times.

Two important points of procedure are as follows: (1) The top stroke is about twice as long as the bottom stroke. This keeps the puddle ahead at the top and prevents sagging. (2) The downstroke from the flat plate to the vertical in the J motion is accomplished by twisting the wrist down and bringing the electrode very close to the vertical plate. This is helpful in keeping the puddle from running and minimizes the spark shower. Do not pull the arm down in making the downstroke. Simply twist the wrist down.

Practice making this weld from right to left as well as from left to right.

The weld should be about 5/8 in. wide, with no undercuts or rolled edges. It should be fairly flat across the top, with smooth, evenly spaced ripples. Make at least three consecutive welds of the correct size and appearance before proceeding to another lesson.

Lesson 36

Making a Flat Butt Weld with Stringer Beads and with a Backup Strip

Select two pieces of 1/2-in. mild-steel plate 6 by 9 in. Bevel one edge on each plate to a 60-deg. angle. Leave 3/32 in. unbeveled as a shoulder at the bottom of each bevel. Place the pieces flat on the welding table, with the beveled edges facing each other (Fig. 148).

Set the current on the welding machine at 125 amp. and 18 volts, with reverse polarity. Use a 5/32-in. reverse-polarity electrode. Using the bare end of the electrode as a gauge, space the inside edges of the beveled plates at a distance equal to the thickness of the rod (Fig. 148). Offset the plates 5/32 in. before starting to weld, to compensate for the contracting action of the weld (Fig. 149).

Inspect your helmet, and assume a comfortable position at the welding bench. Tack the plates together at each end. Make the weld from left to right, if you are right-handed. Keep the electrode straight with the line of travel at all times. Point the electrode into the weld at a 30-deg. angle (Fig. 114).

Strike the arc at the left end of the joint. Hold the electrode stationary until the arc is fusing into the plates; then move forward, using the whipping tech-

nique. If the spacing of the plates is close enough to permit, keep the electrode traveling straight with the line of travel.

When the spacing of the plates is too wide to use the straight back-and-forth movement in the line of travel or when a hole is melted through the joint, move the

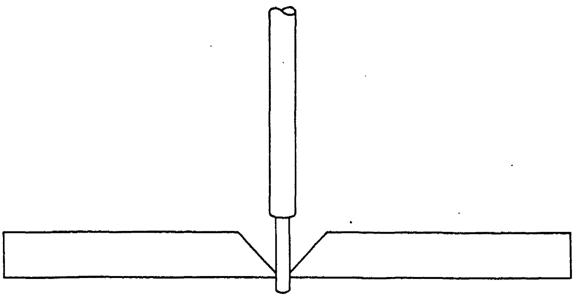


FIG. 148.—Plates spaced by use of electrode.

electrode out of the joint on its forward travel and allow it to travel along the bevel just above the bottom edge (Fig. 150). Move forward about ⅝ in., and then draw the electrode back along the same line and down into the cooling puddle. Allow the electrode to fuse deeply into the puddle, securing good fusion and penetra-

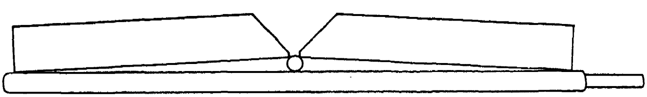


FIG. 149.—Butt weld plates offset to the thickness of a 5⁄32-in. electrode.

tion. Before the puddle drops through, move the electrode ahead on the left side of the bevel for about ⅝ in., allowing a small deposit to be made on the bevel just above the bottom edge (Fig. 150). Draw the electrode back along the same path into the puddle, penetrating deeply into it. On the next stroke, move

ahead on the right-hand bevel. Continue using this V motion (Fig. 150) until the first pass is finished.

The purpose of the first pass is to weld the two bottom edges of the plates together. The penetration bead should extend through the plates at least 3/32 in. (Fig. 151).

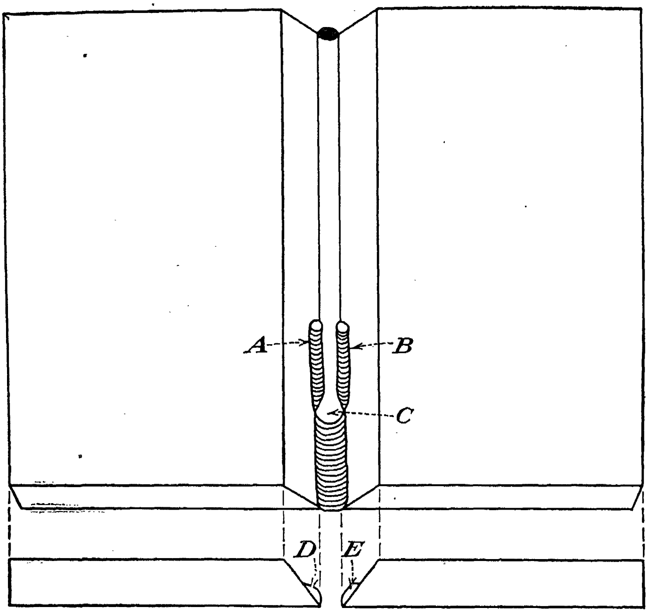


FIG. 150.—Butt weld. *A*, *B*. Stringer beads made just above the bottom edges of the bevels on the forward travel of the V motion. *D*, *E*. End views of the stringer beads. *C*. The crater that must be maintained in front of the puddle.

On the first pass it is necessary to keep a hole in the joint ahead of the puddle at least the size of the diameter of the electrode. This allows for full penetration and is necessary in stopping and starting the weld (Fig. 151).

A different technique is used in restarting a butt weld from that used in restarting a fillet weld. If the

weld is stopped for any reason during its progress, chip and brush the slag from the deposit for at least 1 in. behind the cooled puddle (Fig. 151). Strike the arc about 3/8 in. behind the cooled puddle, hold a long arc, and move forward slowly to the last highest point on the weld puddle (Fig. 151). Hold the electrode still until the puddle begins to melt; then move the electrode forward down the face of the puddle and through the joint to the bottom edge of the penetration

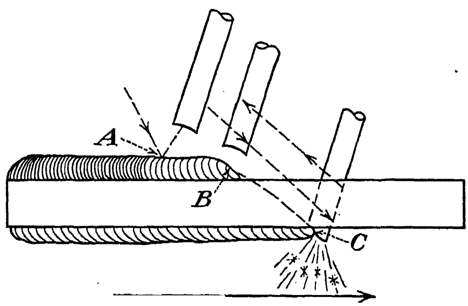


FIG. 151.—Restarting technique. Strike the arc at *A*, move forward through *B* and *C*, securing full penetration. Move the electrode back to *B*, and continue the weld.

bead. Draw the electrode up from between the edges of the joint just before the puddle becomes too fluid. Then move the electrode forward in the V motion to complete the weld (Fig. 150). An examination of the penetration bead should reveal no flaws indicating where the weld was restarted. It is better to have a thick spot in the penetration bead where the weld was restarted than to have a poorly fused section at this point.

Chip and brush the first bead thoroughly before adding the second pass. Raise the current setting on the welding machine to about 150 amp. The second pass is a square U motion (Fig. 152) and is designed to wash out

any impurities or slag pockets trapped along the edges of the first pass (Fig. 152).

Carry the second pass completely out to the end of the joint. Special attention must be given to the bevel next to the welder as the weld is made. The bottom edge of the bevel is out of the welder's sight and is

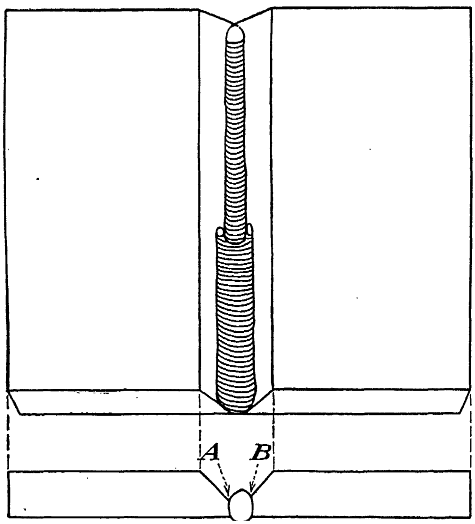


FIG. 152.—Flat butt weld. The square-U motion washes out the slag locked along the edges of the first pass at points A and B.

apt to be poorly fused. Be sure the weld is fusing into this bevel at all times.

The next pass is a stringer bead extending from the face of the bevel just past the center of the second pass. Use the straight back-and-forth whipping technique to make this and succeeding beads. Chip and brush each pass thoroughly before adding other passes. The next pass runs against the opposite bevel, extending to the center of the second pass, and welds to the stringer beads. Add three additional passes, one up each side

of the weld and one in the middle. This should bring the weld level with the top of the plates (Fig. 153).

Finish the weld with three more stringer beads. Deposit the two outside beads, using a small J motion (Fig. 153). Finish with a stringer along the middle of

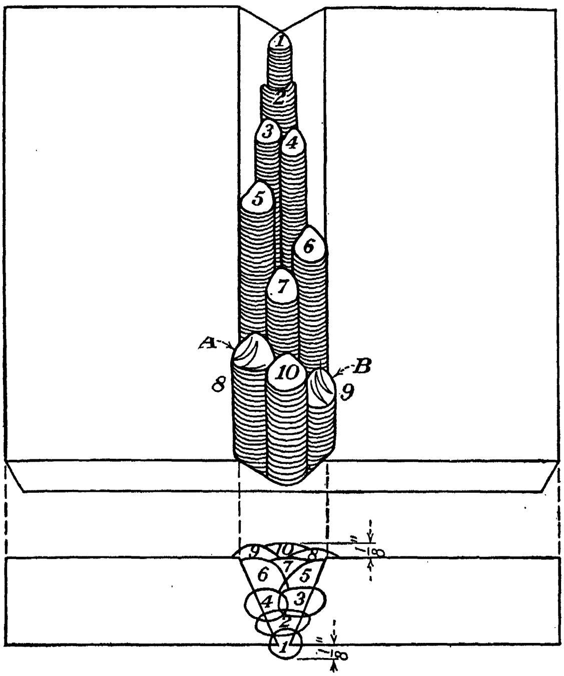


FIG. 153.—A butt weld. The beads are numbered in their order of deposit. The right- and left-hand J motions *A* and *B* are used on the two outside beads to prevent undercutting.

the weld. The top of the weld should be not more than 1/8 in. above the plates. The weld should be not more than 1/8 in. wider than the top edges of the bevels (Fig. 153). It should be slightly rounded across the top, with no undercuts or rolled edges. The ripples on the weld should be very smooth and close together.

Some welding tests require butt welds to be made with a backup strip. The backup strip is a piece of ¼- by 1-in. flat iron, tack-welded to the back of the joint (Fig. 154). When a $\frac{5}{32}$-in. electrode is used for this weld, space the plates $\frac{3}{16}$ in. apart at the bottom edges of the bevels. After the plates are lined and tacked with a backup strip, use a hammer to drive the backup plate tightly against the plates. If a gap is left between the plates and the backup strip, poor fusion and poor penetration are apt to result.

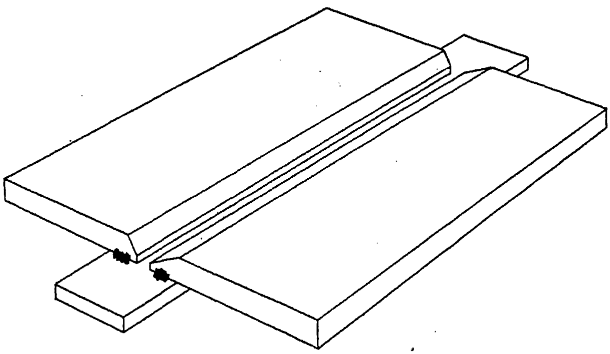


FIG. 154.—A butt weld with a backup strip tacked in position for welding

Set the welding machine at approximately 150 amp. and 18 volts, with reverse polarity, for the first pass. Use a reverse-polarity rod. Use the whipping technique, and fuse deeply into the backup strip and bottom edges of the joint. After the weld is completed, there should be a scale on the back side of the strip. When the scale is removed, there should be an unbroken blue streak the full length of the plate. If the blue streak is broken, this indicates poor penetration at that point. Except for the increased heat for the first pass, complete this butt weld according to the same procedure as for the ordinary flat butt weld.

You should make at least three consecutive butt welds, with the necessary qualifications as to appearance and with five samples out of each weld passing the tests, before proceeding to another lesson (see Testing Weld Samples, page 230).

Lesson 37

Making a Vertical Butt Weld with Weaving Beads, with Stringer Beads, and with a Backup Strip

Select two pieces of ½-in. mild-steel plate 6 by 9 in. Bevel one edge of each plate at a 60-deg. angle. Place them flat on the table, with the bevels facing each other. Space the plates $\frac{5}{32}$ in. apart at the lower edge of the bevels. Set the current on the welding machine at about 130 amp. and 15 volts. Inspect your helmet.

Offset the plates for welding (Fig. 149), and tack them together. Stand the plates on end in a vertical position, for the weld is to be made by progressing from the bottom of the plates to the top.

Keep the electrode straight with the line of travel and pointing directly into, not up at, the weld. Strike the arc at the bottom of the joint. Hold the electrode still until the arc is fusing into the plates. Then advance the arc with short whipping strokes of the electrode directly in the line of travel.

Advance the electrode approximately ⅜ in. on the forward travel, melting the edges of the bevel as it moves. Pull the electrode down into the front edge of the weld, deposit a thin bead, and then move forward, carrying the bead completely out to the top of the plates. To secure full penetration on the vertical weld, the end of the electrode must be flush with the back side of the joint or protruding slightly through the plates (Fig. 157).

If the rod is not pushed far enough into the joint on the first bead, the melting metal will not force itself through the joint but will flow back into the puddle, leaving a sunken area where the penetration bead should be.

If the crack, or spacing, between the plates is too wide for the whipping stroke directly in the line of travel, use the V motion learned in making the flat butt weld. Use the same technique to restart a bead as that used for the flat butt weld.

Chip and brush each bead thoroughly before additional metal is deposited. The second pass is a square U bead (Fig. 152). Hold a short arc, and wash out the slag along the edges of the first bead. Remember that in the square U motion it is necessary to move rapidly across the back of the puddle to keep the weld flat and to prevent sagging. As successive beads are deposited, the plates will become increasingly hot. The current on the welding machine may be reduced, but the best method is to move more rapidly as the weld nears the top of the plates to compensate for the growing heat.

Bring the weld up level with the face of the plates, using the square U motion. Do not swing the electrode in a half circle as it is advanced in the square U motion.

On the final pass a variation of the square U motion is used (Fig. 120). Instead of moving the electrode straight up the edge of the joint in the forward travel, move toward the center of the weld about ⅛ in. on the right side; draw the electrode straight back over the same path, holding it briefly at the edge of the weld to ensure full fusion and correct size; and then move up one-half of the last deposit. Bring the electrode rapidly across the weld puddle to the left side of the weld and forward toward the center of the weld, then back in the same path. Make a brief pause to allow the deposit to fill in.

The electrode is then moved up one-half of the last deposit. Move rapidly across the puddle to the right side. Allow the weld to extend 1/16 in. past the edges of the bevels into the plates (Fig. 120).

This modified motion prevents undercutting at the edges of the weld and keeps the weld fairly flat and smooth across the back. The ripples should be very close together.

If it is required to make the vertical butt weld with stringer beads, use the procedure outlined for the first two passes with the weaving bead. Then, after chipping and brushing the weld thoroughly, deposit stringer beads to fill the joint, using the same procedure as for the flat butt weld. After the weld is level with the face of the plates, finish with three additional passes, one up each side and one in the middle to complete the weld (Fig. 153).

When making the two outside finish beads, move the electrode in a whipping stroke straight up the line of travel along the top edge of the plate (Fig. 153) for about 5/16 in. Then move the electrode back into the weld with a J motion. This motion fills in the edge of the weld and secures full fusion. The center finish bead is made with a straight back-and-forth whipping stroke straight in the line of travel.

The weld should be not more than 1/8 in. higher than the surface of the plates. It should be not more than 1/8 in. wider than the top edges of the bevel. The ripples of the weld should be smooth and very close together.

If it is required to make the vertical butt weld with a backup plate, observe the precautions specified for the flat butt weld. Use enough heat on the first pass to ensure full penetration and fusion into the backup strip.

After the scale is removed from the bottom of the backup strip, there should be an unbroken blue strip showing. If the blue strip is broken, this indicates poor penetration at that point.

Make at least three consecutive welds, with the necessary appearance qualifications and with five samples from each weld passing the tests, before proceeding to another lesson (see Testing Weld Samples, page 230).

Lesson 38

Making an Overhead Butt Weld with Stringer Beads

Select two pieces of ½-in. mild-steel plate 6 by 9 in. Bevel one edge on each plate at a 60-deg. angle. Place the plates on the bench. Space them 5⁄32 in. apart at the bottom edges of the bevels. Set the welding current at approximately 125 amp. and 20 volts, with reverse polarity. Inspect your helmet.

Tack-weld the plates on each end. Offset the plates 5⁄32 in. (Fig. 149) to allow for the normal distortion caused by contraction of the weld.

Suspend the plates at eye level, with the open face of the bevels turned down. Do not stand in such a position that the electrode is drawn directly to you in the puddle or so that the electrode is pushed directly away from you. If you are right-handed, stand just to the right of the weld. The body should be turned slightly away from the joint so that you are only partly facing the weld past the left shoulder. This position enables you to see the fore edge of the crater and at the same time to watch the finished bead as it is made. This position also places you out of the direct path of the shower of sparks and hot particles of metal leaving the weld (Fig. 155).

Keep the lead cable looped over the shoulder to prevent drag upon the electrode holder. The back of the

knuckles should be turned up (Fig. 141) while the electrode holder is being used, to prevent hot metal from lodging on the glove. Support the right wrist with the left hand to steady the arc. If the upper part of the left arm is held tightly against the left side of the body, a much better balance will be maintained.

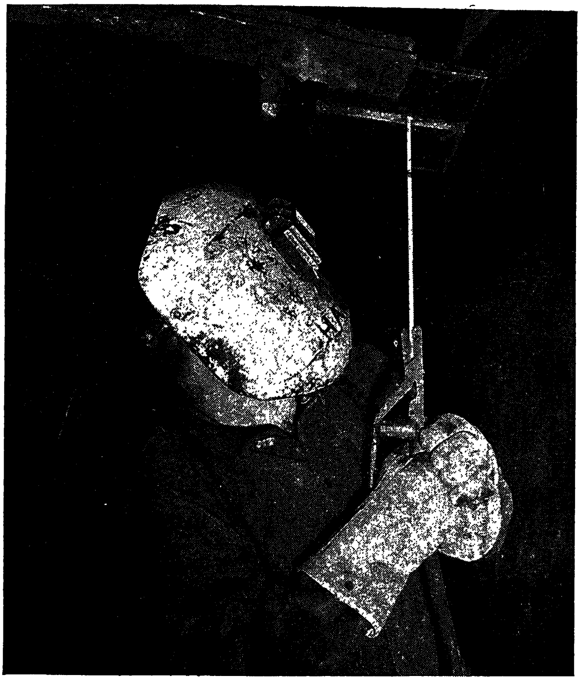


FIG. 155.—Making the overhead butt weld. Welding from left to right. (*Courtesy of Bob Kennedy, California Polytechnic Institute.*)

Use a $\frac{5}{32}$-in. reverse-polarity electrode. Holding it straight with the line of travel, point it into the puddle at a 30-deg. angle (Fig. 156). If the electrode is not kept straight with the line of travel, it will dig too deeply on the side of the weld to which it points, causing a hole in the joint or poor fusion on the opposite side of the joint.

Strike the arc at the left end of the plate. Hold the electrode stationary until the arc is fusing; then move straight along the line of travel, using a short whipping stroke. On the forward travel, pull the electrode slightly down so that a long arc is held. On the backswing, bring the electrode just to the edge of the previously deposited metal, holding a short arc (Fig. 157). The end of the electrode must protrude slightly through the joint or must at least be flush with the back of the joint in order to force the penetration bead through the plates. If the electrode is held just below the surface of the back of the joint, the edges of the bevels will melt

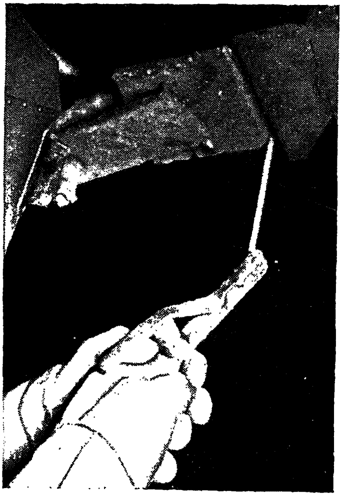


FIG. 156.—Overhead butt weld.

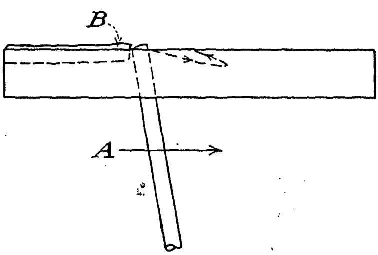


FIG. 157.—Side view of butt weld. *A*. Direction of welding. *B*. Penetration bead.

and flow down, leaving a depression along the back of the weld instead of a penetration bead (Fig. 158).

Chip and brush the deposited beads thoroughly before adding more metal. Use a square U bead on the

second pass to wash out slag along the edges of the first bead.

Move forward fast enough to keep the deposit flat. As on the flat butt weld, add stringer beads until the weld is brought level with the face of the plates. Hold a short arc, and use a short whipping stroke on all stringer beads. Be sure the puddle is flowing cleanly, with the slag washing to the edge of the bead.

Use three stringer beads to finish the weld. On the outside stringer beads, use the same right- and left-hand

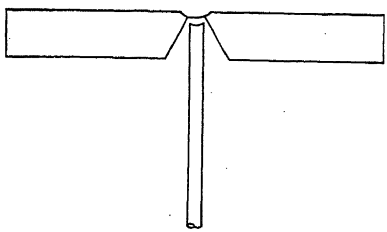


FIG. 158.—End view of overhead butt weld showing incorrect position of electrode.

J motions to keep the edges of the weld well feathered into the plates, without undercuts. The center, and last, stringer bead is made with a short whipping stroke, fusing well into the outside beads.

The overhead weld must have the same appearance and qualifications as the flat butt weld. If a backup strip is used in making the overhead butt weld, observe the precautions suggested for the flat and vertical butt weld with backup strips. If the overhead butt weld is to be made with weaving beads, use the technique recommended for the flat butt weld.

Make at least three consecutive welds, with five samples from each weld passing the tests (see Testing Weld Samples, page 230).

Lesson 39

Making a Horizontal Butt Weld with Stringer Beads and a Cover Bead

Select two pieces of ½-in. mild-steel plate 6 by 9 in. Bevel one edge on each plate to a 60-deg. angle. Place the plates flat on the bench. Space them 5⁄32 in. apart at the bottom edges of the bevels.

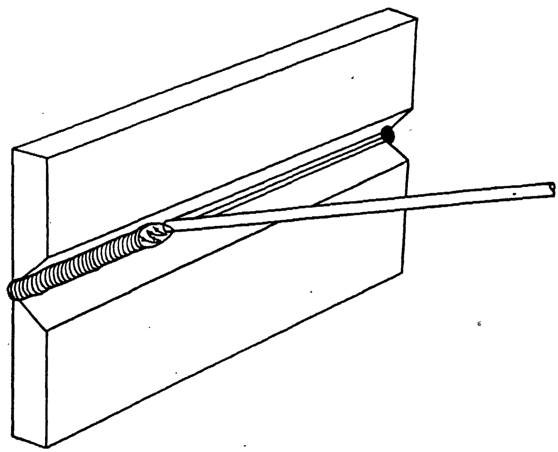


FIG. 159.—Horizontal butt weld. Arrows indicate direction of electrode movement.

Set the current on the welding machine at approximately 130 amp. and 18 volts, with reverse polarity. Use a 5⁄32-in. reverse-polarity electrode. Inspect your helmet.

Tack-weld the two plates at each end. Suspend the plates in a vertical position, with the joint in a horizontal plane (Fig. 159).

Strike the arc at the left end of the joint. Be sure the arc is fusing well into the plates; then move forward, using a short whipping stroke. Keep the electrode

pointing straight into the weld (Fig. 160). Lift the electrode slightly higher on the backstroke to weld into the upper bevel (Fig. 159).

Chip and brush each deposit thoroughly before adding other beads. Make the second stringer bead at the bottom edge of the first bead (Fig. 161). Use a straight back-and-forth whipping motion in the line of travel

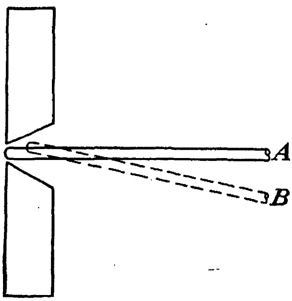


FIG. 160.—Side view of horizontal butt weld. *A*. Position of electrode on first pass. *B*. Position of electrode on third pass.

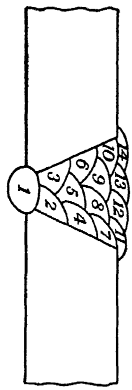


FIG. 161.—Side view of horizontal butt weld showing order of weld deposits.

Be sure the puddle is fusing into the first pass and the bevel.

The third pass is made against the top bevel. On this pass the electrode may be pointed slightly up to avoid an undercut on the top bevel (Fig. 160).

Use a short arc on all the beads in this weld. Continue depositing beads until the weld is brought flush with the face of the plate.

If this weld is to be completed with stringer beads, start at the bottom edge of the joint and deposit a stringer bead half in the plate and half in the weld. Each bead thereafter is deposited in the same manner,

advancing half a bead at a time. The last bead, or top bead, should be made half in the plate and half in the last previous bead. This method of depositing beads prevents sagging or undercutting. The top of the weld should be fairly flat, with no channels between the beads. Care must be used that the weld does not become heavier at the top as successive beads are laid (Fig. 161).

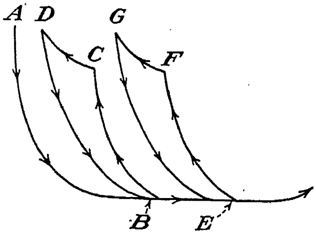


FIG. 162.—Direction of travel of the electrode in making a weaving bead on a horizontal butt weld.

If it is necessary to finish the weld with a weaving bead, use the motion shown in Fig. 162. If a backup strip is used, observe the precautions noted for previous plates.

You should make at least three consecutive welds, with the necessary appearance qualifications and with five samples from each weld passing the tests, before proceeding to another lesson (see Testing Weld Samples, page 230).

LESSON 40

Making a Rolling Pipe Butt Weld

Use two pieces of 8-in. standard line pipe about 12 in. in length. Using a roundabout, draw a straight chalk line around one end of each piece of pipe. A roundabout is a piece of rubber belting or heavy gasket paper about 3 in. in width and at least 4 in. longer than the circumference of the pipe to be marked (Fig. 163).

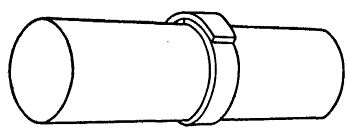


FIG. 163.—Pipe and roundabout.

With the cutting torch, scarf or bevel the marked ends of the pipe at about a 60-deg. angle. When beveling

pipe, always hold the cutting torch behind the chalk line so that the longest point of the bevel is directly under

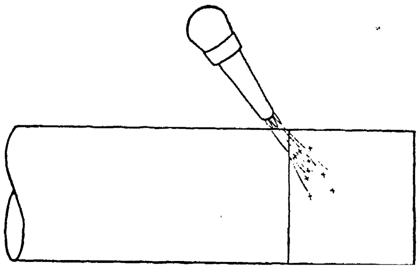


FIG. 164.—The cutting torch is held behind the chalk line when cutting a bevel.

FIG. 165.—Rolling pipe weld. (*Courtesy of Lincoln Electric Co.*)

the chalk line as the cut progresses, maintaining the over-all measurement (Fig. 164).

Line the beveled ends of the pipe, keeping the two pieces of pipe in a straight line. Space the beveled ends

about $5/32$ in. apart. Set the current on the welding machine at about 135 amp. and 15 volts, with reverse polarity. Use a $5/32$-in. reverse-polarity electrode (Fig. 165).

Make one tack weld on the top center of the pipe joint. Then, tack just below the center of the joint on each side. Roll the pipe over, and make a tack weld on the opposite center (Fig. 166). During welding, the joint should be in a position to be easily rolled either on rollers or on blocks (Fig. 166).

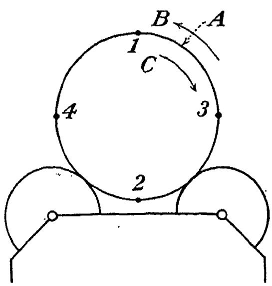


FIG. 166.—Pipe resting on rollers. *A*. Top shoulder of joint. *B*. Direction of welding. *C*. Direction of pipe movement. Numbers indicate order of tack welds.

Begin the weld midway between two tacks. Strike the arc at point *A* (Fig. 166). Build a small puddle, and move forward, using the whipping technique. The object of the first pass is to weld the bottom edges of the vee together with full penetration. As the weld progresses, roll the pipe toward you. Keep the puddle as nearly as possible at point *A* (Fig. 166). The puddle is easy to control in this position.

If the crack, or space, between the bevels is too wide, use the V stroke (Fig. 150). If the crack comes together, making it impossible to penetrate completely through the joint with the electrode, use the cutting torch and cut a thin piece from one of the bevels to widen the crack. It is better to space the joint sufficiently during lining and tacking to allow for contraction during welding. Cutting on one side to open a tight crack, though necessary to obtain full penetration, will allow the joint to pull to that side and out of line, an important factor in a precision fit.

Use the regular procedure for restarting a weld (Fig. 151).

As the first pass approaches completion, special attention must be given to making the tie-in between the beginning of the weld and the finishing puddle (Fig. 167). Leaks on pressure lines often occur at this point in the weld if the correct procedure is not used. Chip and brush the weld at the starting point thoroughly for at least 2 in. back on the bead. As the puddle

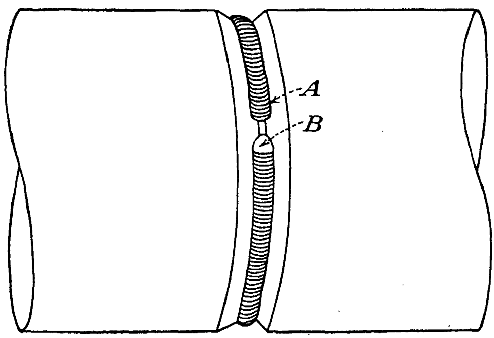


FIG. 167.—As puddle *B* approaches beginning of weld *A*, fuse deeply into point *A*.

reaches this end of the bead, hold the arc steadily against the cold metal until it melts and flows back into the puddle. Keep fusing into the end until the puddle shows a tendency to fall through; then move forward with the arc, melting into both sides of the previously deposited bead for at least 1 in. Withdraw the electrode slowly from the puddle to keep from leaving a gas pocket or a depression in the puddle. Be sure that it does not become necessary to stop to change electrodes during this finishing process.

Chip and brush the first pass thoroughly before making the second pass. Raise the current setting on the welding machine to 115 amp. Begin the second pass at a

point about 4 in. from the first starting point. Roll the pipe while welding to keep the puddle at point *A* (Fig. 166). Use the square U motion on the second pass. Observe the same precautions in finishing this bead as on the first pass. The second pass should bring the weld level with the top edges of the bevels. It should fuse into the bevels of the pipe but does not extend into the pipe past the top edges of the bevels.

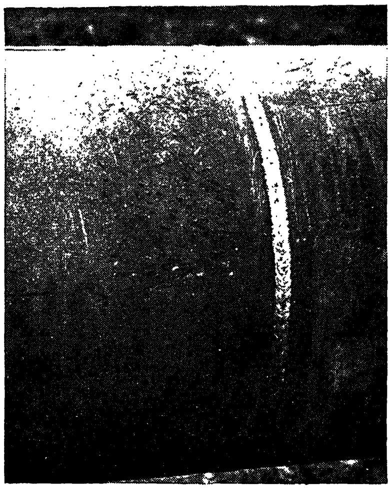


FIG. 168.—Finished pipe weld. (*Courtesy of Lincoln Electric Co.*)

Chip and brush the second pass thoroughly before adding the third pass. Use the same motion on the third pass as on the finish bead in the vertical butt weld, to ensure perfect fusion into the pipe, no undercuts along the edge of the weld, and a fairly flat surface across the back of the weld. The smooth, even ripples should be about ½ in. wide and ⅛ in. above the pipe (Fig. 168).

This weld may be made with a 5⁄32-in. electrode for the first pass and a 3⁄16-in. electrode for the second pass. In this case a third pass will not be necessary. Move the

$\frac{3}{16}$-in. electrode in an inverted T motion to secure full fusion and penetration and to build the weld to the correct size (Fig. 169).

While the previously mentioned method of welding is required on many jobs, a different technique is used in high-speed pipe-line work. The weld puddle is held at the same point as in the previous method, but the weld is brought forward down the joint and the pipe is rolled away from the operator to keep the weld puddle at the correct level (Fig. 170).

Set the welding current at 135 amp. and 20 volts, with reverse polarity. Use a $\frac{5}{32}$-in. reverse-polarity electrode. Line and tack the joint as previously suggested.

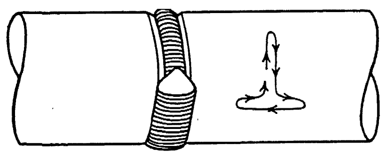


FIG. 169.—Inverted tee motion used in making finish bead.

Strike the arc at point *A* (Fig. 166), and build a small puddle. Draw the electrode to you, using a whipping stroke. Roll the joint away from you as the weld progresses, keeping the puddle in the section between the top of the pipe and point *A* (Fig. 166).

Bring the electrode just to the edge of the puddle as the arc is moved back into the weld. If the puddle becomes too fluid or seems to be dripping through the joint, carry the electrode higher into the puddle on the back swing in order to deposit more metal.

Chip and brush the first pass thoroughly before depositing the second pass. Set the welding current at 150 amp. and 20 volts. Pull the electrode to you, using the whipping stroke. Fuse well into both edges of the first pass. The speed of the welding is much faster

with the downhill method, but the deposit is not so heavy. Consequently, a third pass will be necessary.

Chip and brush the second pass thoroughly before adding the third pass. Use the whipping stroke, and make sure that the edges of the weld are fusing well into the pipe. The weld should be about ⅜-in. wide and flat across the top, with smooth, closely spaced ripples.

Fig. 170.—Making a rolling pipe weld. (*Courtesy of Lincoln Electric Co.*)

Make three welds with each method, taking 17 test samples from each weld. Every sample should pass the tests before proceeding to the next lesson (see Testing Weld Samples, page 230).

Lesson 41

Making an Overhead Pipe Butt Weld

Line and tack two pieces of 8-in. standard line pipe as in the previous lesson. Suspend the pipe so that

there is an 18-in. clearance under the pipe. Set the welding current at 120 amp. and 15 volts, with reverse polarity. Use a $\frac{5}{32}$-in. reverse-polarity electrode, although a $\frac{1}{8}$-in. electrode may be used for the first pass. The technique for the first pass is identical in either case (Fig. 171).

The weld is to be made by progressing from the bottom of the joint to the top (Fig. 171). If right-

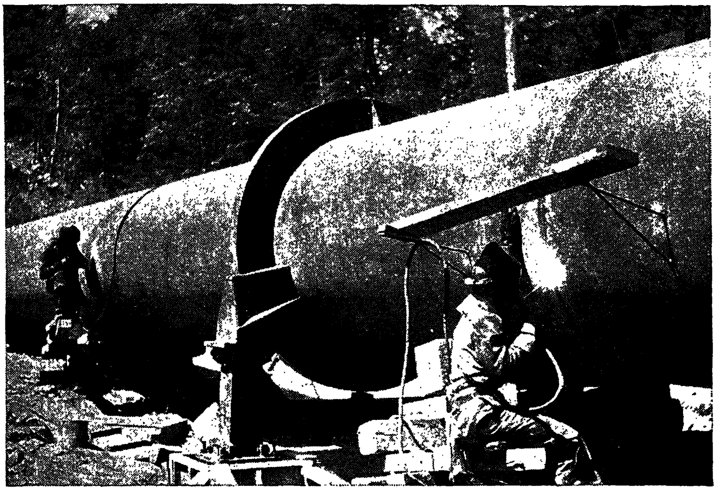


FIG. 171.—Overhead welding. (*Courtesy of Lincoln Electric Co.*)

handed, lie down on the right side beside the pipe, facing the joint. Slide the right arm forward until the weight is off the right shoulder. This position permits easy movement of the electrode holder held in the right hand. Place the left foot against the pipe. Set the left elbow against the left leg with the left hand supporting the right hand. Place a block under the head for support until you become accustomed to this position. Adjust your helmet, and strike the arc at point *A* (Fig. 172). This point is past center. Starting past

the center facilitates starting the weld on the opposite side of the joint.

Keep the electrode straight with the line of travel and pointing into the puddle at a 30-deg. angle. Build up a small puddle, and draw the electrode toward you, using a whipping motion. As the weld progresses, the electrode must be thrust deep into the joint on the backstroke in order to obtain full penetration. If the joint is too close to the ground, it may be necessary to bend the electrode in order to keep it in the correct position. Bend the electrode as close to the tongs as possible to avoid waste of rod.

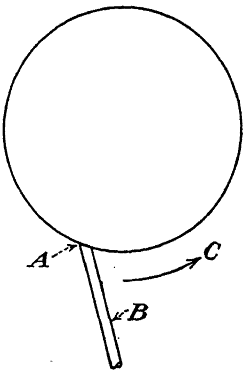


FIG. 172.—Overhead pipe weld. *A*. Starting point of weld. *B*. The electrode. *C*. Direction of weld.

As an aid in maintaining a steady arc, push up hard with the right hand holding the tongs, and by keeping the left hand over the right regulate the strokes and steady the arc.

The position of the electrode must be continually changed as the weld advances to keep the electrode in the line of travel and pointing into the weld (Fig. 173).

As the weld leaves the bottom of the joint and progresses up the side of the joint, the most difficult position in pipe welding is encountered. Keep a short arc, and do not make long strokes with the electrode. Do not allow the electrode to point up at any time. Carry the weld to the top and past the center of the joint.

Chip and brush the end of the first bead at the bottom of the pipe for at least 2 in. Assume the same prone position facing the unwelded portion of the joint. Set

the welding current at 135 amp. Strike the arc on the previously deposited bead about 1 in. from the beginning.

Using a square U weaving motion, carry the puddle toward you, fusing well into the top and sides of the bead. Use the whipping stroke as soon as the arc reaches the unwelded portion of the joint. Bring the weld up the side of the pipe to the top. Change your position and that of the electrode in order to be as comfortable as possible, and keep the electrode in the correct position as the weld progresses. When the top of the pipe is reached, use the correct finishing technique to complete the tie-in of the ends of the first bead.

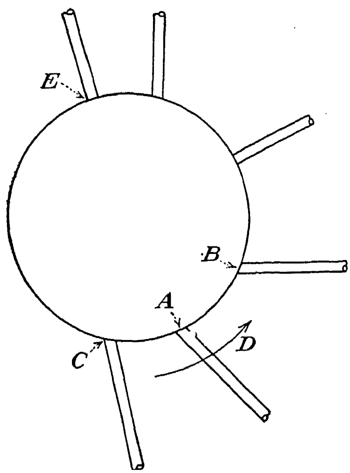


FIG. 173.—Overhead pipe weld showing position of electrode as weld progresses. *A* to *B*. Most difficult welding area on pipe weld. *C*. Starting point of weld. *D*. Direction of weld. *E*. End of first half weld.

Chip and brush the first pass thoroughly before adding the second pass. Assume the same position and place the electrode as for the first pass. Use the square U motion, and keep a short arc, and consequently a small puddle, as the weld crosses the difficult area of the joint (Fig. 173). Complete the second pass in the same manner as the first pass.

Chip and brush the second pass thoroughly before adding the third pass. Use the same technique in depositing the third bead as in the weaving motion on the rolling pipe weld and the vertical butt weld (Fig. 169).

On the first few overhead pipe welds there may be a tendency for the weld metal to sag as it is deposited.

If the puddle does not become fluid enough to form a drop, it will not drip or sag. If the electrode is held briefly at each edge of the puddle and moved rapidly across the puddle on the cross stroke, advancing by one-half of the previously deposited bead, the weld will not sag but will be well fused into the pipe. It will appear flat across the top, with smooth, evenly spaced ripples.

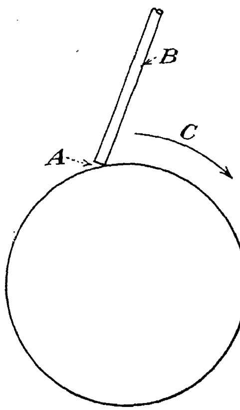


Fig. 174.—Overhead pipe weld. *A*. Starting point of weld. *B*. The electrode. *C*. Direction of weld.

If it is necessary to make the overhead weld by the downhill method of welding, line and tack the joint as before. Suspend the weld to allow a clearance of 18 in. under the pipe. Set the welding current at 140 amp. and 18 volts, with reverse polarity. Use a 5/32-in. reverse-polarity electrode.

Keep the electrode straight with the line of travel and pointing into the weld. Strike the arc at point *A* (Fig. 174). Build up a small puddle. Holding a short arc, bring the weld across the top of the pipe and down the side to a point just past the center of the bottom of the pipe. Use a short whipping stroke. The end of the electrode should be held so closely into the joint that at times the actual arc is partly buried in the puddle (Fig. 175).

As the arc comes down through the difficult section of the pipe weld, be sure that the end of the electrode is forced up into the crack in order to secure full fusion and penetration. Complete the second half of the first pass. Take care to obtain good fusion during the tying in of the ends of the weld.

Chip and brush the first pass thoroughly before adding the second pass. The second pass is made with a 3/16-in.

reverse-polarity electrode. Set the current at about 155 amp. and 18 volts. Make the second pass according to the same procedure as the first pass. Fuse well into the edges of the first pass.

The third and final pass is made with a 3/16-in. electrode in the same manner as the first two beads. Use the

FIG. 175.—Downhill welding on pipe line. (*Courtesy of Lincoln Electric Co.*)

whipping stroke as the electrode is advanced. Move the electrode widely enough when in the puddle to fill in all low spots and to keep the weld fairly flat and smooth, with no undercut edges.

Make three welds with each method. Cut 15 samples from each weld, and make sure that all test requirements are met before regarding this lesson as complete.

CHAPTER XVII

EXPANSION AND CONTRACTION

When heat is applied to metal, the metal grows, or stretches. This action is called *expansion.* As the metal cools, it shrinks, or contracts. This action is called *contraction.* If the metal is restrained during welding and unrestrained during cooling, it will tend to shrink in length. Welding on one side of a plate or bar of iron will draw the plate or bar out of a straight line

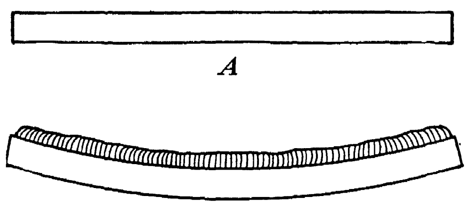


FIG. 176.—*A*. Straight bar. *B*. Bar curved after deposit of weld.

toward the weld as the latter cools (Fig. 176). When butt welds are made, the outside edges of the plate draw toward the crowns of the welds as these cool.

In cooling, the weld shrinks and exerts a pulling force. The outside ends of butt-weld plates are free to move. Consequently, they draw up out of a straight line in following the line of pull. If during welding and cooling the plates are restrained and unable to move, the result is to leave the weld and the area adjacent to it in stress. If the weld is in light-gauge material, the plates have a tendency to warp or buckle in an effort to relieve the stress. If the plates are of heavy material, there is a

strong possibility of the weld or the area adjacent to it cracking. Stress is present in all welding jobs.

Expansion and contraction cannot be eliminated in welding, but they may be controlled. To control the shrinking or contracting action of a weld, allowances must be made so that the welded piece is straight and

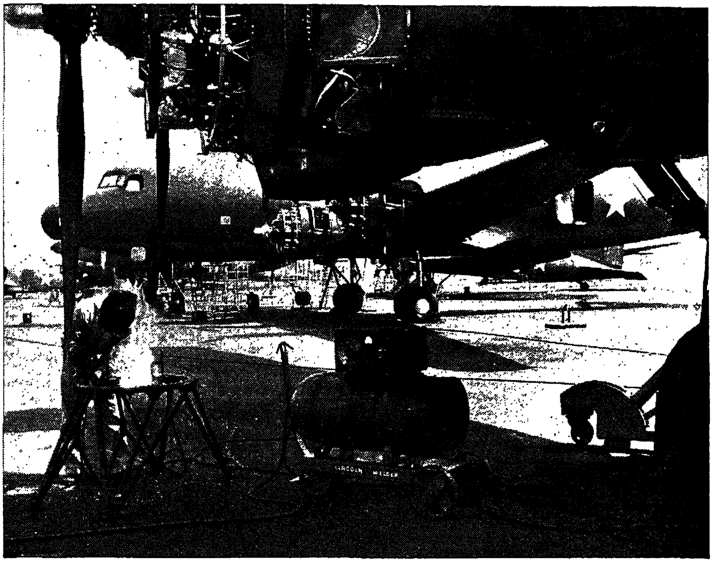


FIG. 177.—Welding an aircraft engine mount. (*Courtesy of Lincoln Electric Co.*)

as free as possible from residual stress when the weld is completed (Fig. 177).

There are a number of methods of equalizing the strains and relieving the stress caused by arc welding.

1. Offsetting the joints to be welded.
2. Removing heat from plates during welding.
3. Using tack welds to offset the joint.
4. Veeing out cracks to prevent distortion.
5. Welding on opposite sides to equalize strain.

6. Preheating.
7. Peening the weld.
8. Welding by the skip method.
9. Welding by the stagger method.
10. Using the step-back procedure.

Butt welds, for example, are spaced to allow full penetration even though the plates are steadily drawing

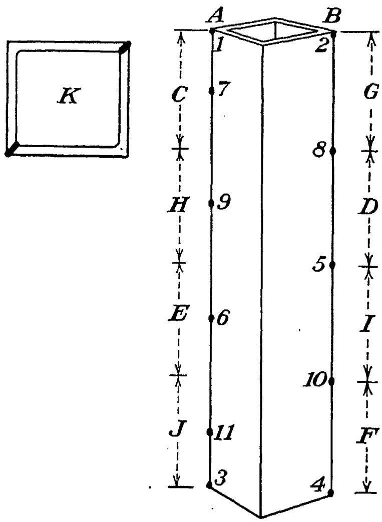


FIG. 178.—*K*. End view of angle irons tacked together to form box. Numbers indicate order of tack welds. Letters indicate order of weld deposits.

together during welding. The plates are offset about $\frac{5}{32}$ in. from a straight line (Fig. 149) to allow for the normal distortion caused by the contraction of the cooling weld.

If two pieces of angle iron were faced toward each other to form a box and tacked to hold them in line during welding, it would be necessary to tack on alternate sides (Fig. 178) in order to equalize the strain. The procedure of welding would have to be in the same

sequence as the tacks to keep the angle irons from warping (Fig. 178). If the weld were made continuously, the box would be drawn toward side *A* as the cooling weld contracted. Welding continuously on side *B* would straighten the box to some extent but not to the correct degree. It must be welded alternately to equalize the strain (Fig. 178) and keep the box straight.

It is often necessary to set up a distortion by tack welding in order that the cooling weld may draw the welded piece into a straight line. In Fig. 179, the broken bearing bracket must be perfectly straight after welding since any distortion will cause the bearing to wear. Side *A* must be smooth, whereas side *B* may have any amount of weld deposit desired. Vee out side *A* about 1/16 in. deep to allow a sealing bead to be welded in. The bead may be ground off flush without leaving a crack. Vee out side *B* deeply enough to obtain full strength. After lining, tack at points *C* and *D*. Place the first tacks in a neutral position if possible. Make a thin sealing bead or a long tack along side *A*. Allow this bead to cool slightly, which will cause the bracket to be drawn toward side *A*; then make a weld on side *B*. This weld must be made quickly with a minimum deposit. After cooling, the bracket will be perfectly straight. A minimum deposit, as emphasized in the previous lessons, causes less stress than a large deposit.

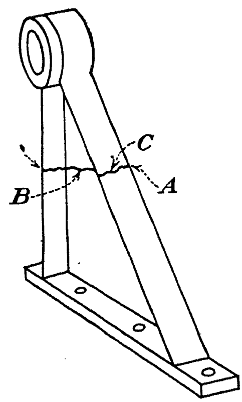


FIG. 179.—Cast-iron bearing bracket showing fractures.

On certain jobs such as building up worn surfaces on one side only, distortion may be avoided by drawing the

heat from the weld as it is made. If a large surface, such as a crusher block on a mill, must be built up on one side, distortion will undoubtedly occur.

Place the block in a tub of water until the top surface is barely above the water line. Keep the water flowing slowly into one end of the tub and slowly out the other end. The circulating water will drain the heat from the block to a point where no distortion will occur.

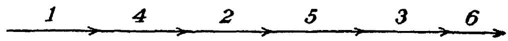


FIG. 180.—Skip method of welding.

In welding cast iron and aluminum, it is often desirable to preheat the object to be welded in order to expand the metal, relieving any residual stress and equalizing the strain of the cooling weld. This is explained more fully on page 111.

Peening the weld metal as it is cooling to counteract the shrinking is desirable under some circumstances (page 221).

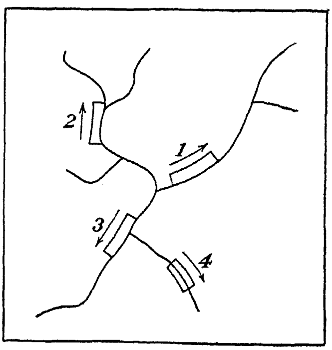


FIG. 181.—Stagger method of welding.

There are three methods of depositing beads, the skip, the stagger, and the step-back. The skip method is often employed on a long seam (Fig. 180) to avoid running a continuous weld and to allow the heat to dissipate into the object being welded.

The stagger method is used primarily in welding cast iron, aluminum, or pot metal, the object being to avoid a great degree of heat in one area while another area remains cold. This method consists in depositing short

beads in all directions, where there is a series of cracks, always working from the center toward the outside edges of the object in order to carry the heat to the outside and avoid any locked-up, or residual, stress in the casting. Under this system no one area contains

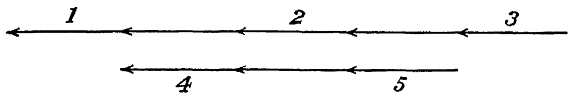


FIG. 182.—Stepback method of welding.

more heat than another, and the weld metal is deposited evenly over the area to be repaired (Fig. 181).

The step-back method is used to normalize the heat absorbed by the base metal during welding and, at the same time, to normalize the stress set up by the cooling weld metal. It is used on long seams and parts where the area to be welded or built up is on the edge of the object, as the ways of a base (Fig. 182).

CHAPTER XVIII

CAST-IRON WELDING

Cast iron is used in the manufacture of tools and equipment because it can be cast into intricate shapes, is easily machined, and is economical to produce, but it has very little ductility, is subject to rapid expansion and contraction, and is easily fractured (Fig. 183).

If redesigning the broken casting for a steel part is not practical, cast iron may be repaired by arc welding (Fig. 184). The actual fusion-welding process of cast iron is identical with that of welding steel. But in cast-iron welding more consideration must be given to residual, or locked-up, stress resulting from uneven heating and cooling during the welding. Hard spots in the weld, distortion of the casting, and additional cracking are direct results of improper cooling and residual stress.

There are several types of cast iron ordinarily encountered in welding gray cast iron; white, or chilled, cast iron; and malleable iron (see page 107). White cast iron is cast iron that has been subjected to rapid cooling at the foundry, making it very brittle. The moldboards of certain plows are made of chilled, or white, cast iron. Bronze welding is the only satisfactory process of repairing this metal in order to have it retain its original strength.

Malleable iron, owing to its composition, may be described as cast iron with more ductility, or ability to bend, than ordinary cast iron. Bronze welding is the only satisfactory method of repair for this metal.

Gray cast iron is the most common of all cast irons, and the welding procedures to be described are applicable to it. Bronze welding of gray cast iron is very successful; but on jobs where it is necessary to have the color of the weld match the base metal, the arc-welding process

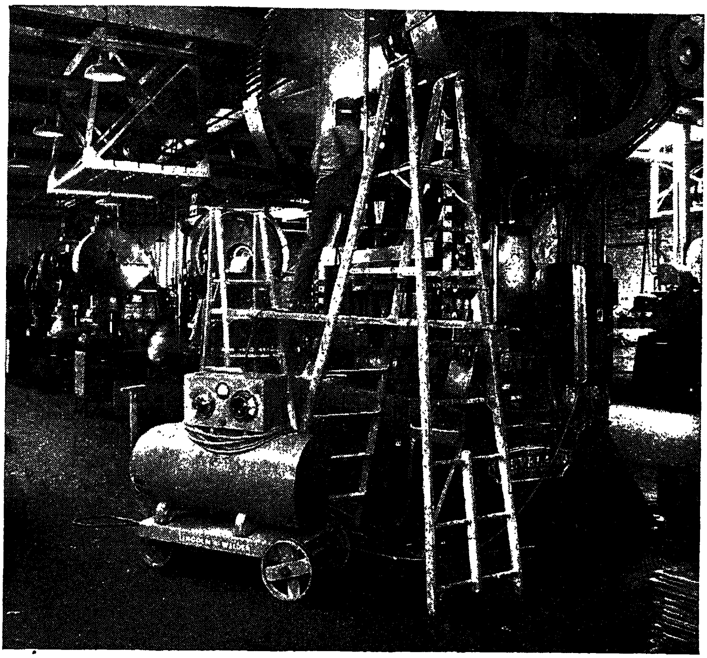


FIG. 183.—Welding cast-iron gear. (*Courtesy of Lincoln Electric Co.*)

is desirable. The welding procedure on cast iron involves the following:

1. Cleaning the casting thoroughly around the area of the break.
2. Locating all the cracks in the broken area.
3. Aligning the broken pieces.
4. Veeing out the cracks preparatory to welding.
5. Making allowances for normal contraction.

6. Preheating the casting.
7. Tacking the joint or crack.
8. Depositing the weld metal or beads.
9. Stress relieving as the weld progresses.
10. Judging the machinability of the weld.
11. Correctly cooling the casting after welding.

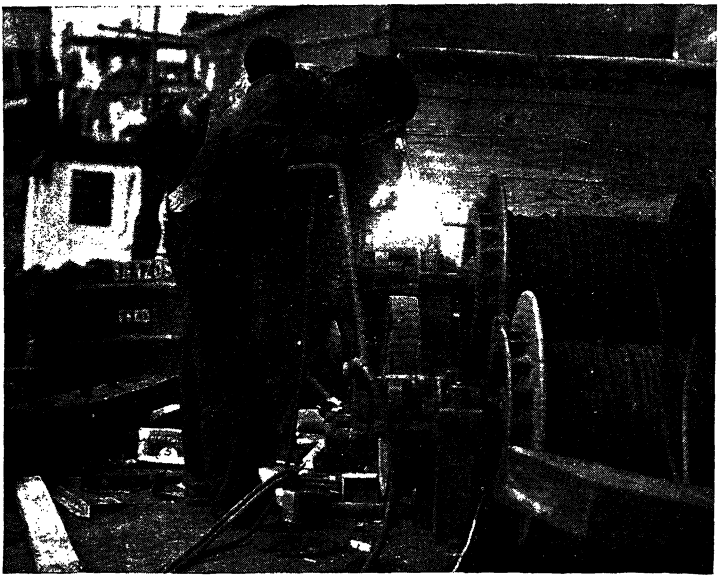


FIG. 184.—Cast-iron repair by arc welding. (*Courtesy of Lincoln Electric Co.*)

A welding job involving most of the preceding considerations was the crankcase of a tractor. This case was badly damaged when a link of the drive chain broke and jammed between the gear and the bottom of the case. The repair was effected without removing the crankcase from the tractor, necessitating welding in the overhead position.

The tractor was placed where no wind could blow upon it during the welding, facilitating the control of

the heat. The crankcase was washed with gasoline to clean the broken area and make it possible to locate the cracks. After the area was washed, tapping lightly with a small hammer set up a vibration that exposed fine cracks not previously visible. A welding torch was used to preheat the case, around the broken area, until the chill was removed, or until it was faintly warm to the touch.

By using a ⅛-in. reverse-polarity electrode on straight polarity with high voltage, the cracks in the casting were rapidly veed out. The depth of the vee equaled about

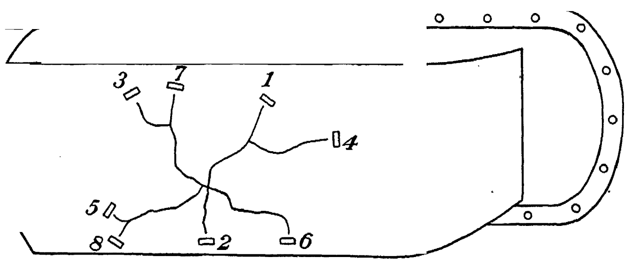


FIG. 185.—Cast-iron crackcase showing fractures. Numbers indicate order of tack welds necessary to prevent creeping of fracture.

three-fourths the thickness of the metal. If the casting had been veed out completely through the metal, with wide cracks, the resulting contraction in that area would have caused further cracks.

In veeing out cast iron, use a short whipping stroke, with the end of the electrode deep in the puddle as it washes the surplus metal out of the crack.

The casting must be warmed again with the welding torch, to increase the heat around the broken area and thus equalize the heat built up during cutting.

Cracks in a casting have a tendency to extend during tacking or welding. This creeping can be stopped by drilling ⅛-in. holes about ¼ in. ahead of the end of the

crack (Fig. 185). If drilling is not practical, a short bead about ½ in. long, welded at right angles from the crack and ¼ in. in advance, will stop the creeping (Fig. 185).

Use a ⅛-in. cast-iron electrode. Set the welding current at approximately 80 amp. and 20 volts, with reverse polarity. Make a tack weld at 2-in. intervals on all the cracks, staggering them to distribute the heat and avoid unnecessary strain in one area (Fig. 181). Stagger the weld deposits in the same manner to avoid too much stress in one area.

Hold a short arc at all times. Run a small bead just large enough to fill the crack. A large bead exerts much more strain on the casting than a small one and does not add to the strength of the weld. Make each bead about 1½ in. in length. Work from the center of the broken area to the outside edges in order to carry the heat to the outside and to minimize locked-up stress. The final beads are made on the outside ends of the cracks.

Do not allow the casting to become red or otherwise to change color outside the weld during welding. Pause after each deposit to allow the heat in the casting to equalize, but not long enough to allow it to drop so low that preheating is necessary before resuming the weld. Clean the scale from the end of the bead before joining a previously deposited bead.

After the crankcase is cool, chip and brush each weld thoroughly and inspect for hair cracks running parallel to the weld or across it. If any are present, do not vee out but run a light bead over them to seal them.

If a crack occurs beside the weld, too large a deposit with the necessarily greater heat is being used and the contracting rates of the weld and parent metal are

unequal. If the arc is drawn too rapidly out of the puddle at the completion of a bead, minute cross checks will probably occur in the cooled puddle. Lap the beads when tying in, to ensure perfect fusion in the juncture of two beads.

A slight hair crack is likely to occur down the center of the bead. Without veeing, seal such a crack with a small bead. If one portion of the case seems to be warmer than the rest, warm again with the welding torch to equalize the heat. Keep all drafts from the casting as it cools.

If it is necessary to make a cast-iron weld with a machinable surface, special precautions must be observed. The first passes may be made with the electrode just discussed, in order to obtain a strong bond with the cast-iron base. Then a mild-steel electrode may be used to make the final passes, leaving a machinable surface. The mild-steel electrode will not weld into the cast-iron base but will weld into the cast-iron arc weld successfully. There are cast-iron electrodes on the market that are designed to build up machinable surfaces.

Cast iron may be welded to steel, permitting the inserting of steel patches in castings where a large piece is missing and the reinforcing of cast brackets with steel webs.

CHAPTER XIX

ALUMINUM WELDING

The welding of aluminum is greatly facilitated by the arc-welding process. Little or no preheating is necessary. Aluminum has a high heat conductivity, and the heat from the weld is rapidly dissipated into the body of the object being welded.

The aluminum electrode has a coating of flux designed to prevent oxidation of the weld metal and to remove any oxide that may be on the plate.

Preparing aluminum for welding is the same as the procedure for mild steel. Pieces ⅛ in. thick or over should be beveled and precautions taken during lining to ensure correct alignment after welding. In some instances, backup plates may be placed under the weld to guard against sagging.

A discarded aluminum cylinder head or crankcase is suitable for practice. Scarf out a crack in the head with a chisel, with the acetylene torch, or with a reverse-polarity mild-steel electrode. If the mild-steel electrode is used, set the voltage very high on straight polarity, use a scraping motion with the arc, and wash out a narrow, deep crack.

Use a 5/32-in. aluminum electrode. Set the current at approximately 135 amp. and 25 volts, with reverse polarity. Aluminum welding requires more heat than does the corresponding thickness in mild steel.

Preheat the starting point of the weld so that the arc will fuse instantly. Hold a short arc, with the electrode

straight with the line of travel and perpendicular to the weld.

Aluminum welding requires a very steady arc; for the electrode will freeze instantly if the arc becomes too short, and the arc will go out if the electrode is lifted too high from the weld. If the weld is stopped during its progress, restart the weld as for the other butt welds.

While it is more practical to weld aluminum in the flat position, it may be welded in the vertical and overhead positions. In order to prevent distortion and avoid stress, use stringer beads and peen the deposits slightly to stretch the weld metal and counteract the normal shrinking action of the weld.

CHAPTER XX

BUILDING UP AND HARD FACING

CARBON ARC WELDING

The carbon-arc welding process differs from the metallic-arc process in that a carbon stick instead of an electrode is held in the tongs. The carbon arc furnishes the heat, ordinarily supplied by an acetylene torch,

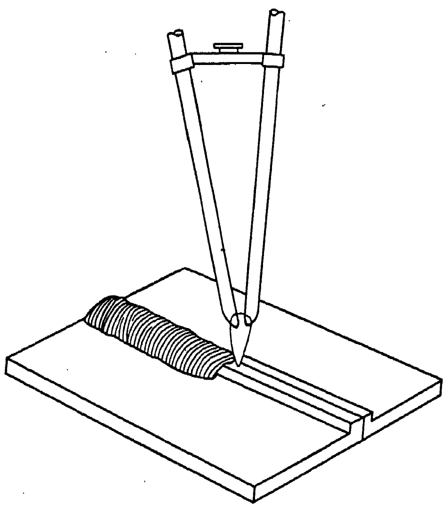


FIG. 186.—Carbon arc used in making a flange weld.

to melt a rod held by the welder in his other hand and thus to weld two pieces of metal together, to do brazing, or to build up worn surfaces. On some joints, such as edge welds or lap welds, the carbon arc may be used to complete the weld without the aid of a filler rod (Fig. 186). This method is often used in the fabrication of aluminum or stainless-steel parts.

The carbon stick is about 12 in. in length, tapering sharply at one end. The end becomes white-hot during welding but does not melt. It gradually disintegrates as welding progresses.

The carbon arc is always used with straight polarity at high voltage. The latter is necessary to maintain the long arc needed in carbon arc welding. The amperage setting will vary with the thickness of the metal to be welded.

If reverse polarity is used, the carbon arc will be erratic and hard to control and will deposit a sooty surface of carbon.

Carbon brazing of galvanized sheet metal is valuable, for only the galvanized coating directly under the bronze weld is removed. The heat is so concentrated in the carbon arc that light-gauge sheet metal is welded with a minimum of distortion.

The carbon arc is an economical method of building up such objects as plow points, cultivator points, and worn surfaces on drawbars.

BUILDING UP AND HARD FACING

Reclamation of worn parts and prevention of wear are important phases of a welder's work. An application of hard facing on the wearing surface of a new part will greatly increase its life. If the part is worn past the point of usefulness, then it should be built up to the original size and a coating of hard facing applied before it is put back in service (Fig. 187).

A bare high-carbon rod is used with the arc-welding process to do the building up. The high-carbon rod is run with reverse polarity and high voltage to keep the rod from freezing and to maintain a steady arc. It is well, in building up with the high-carbon rod, thoroughly

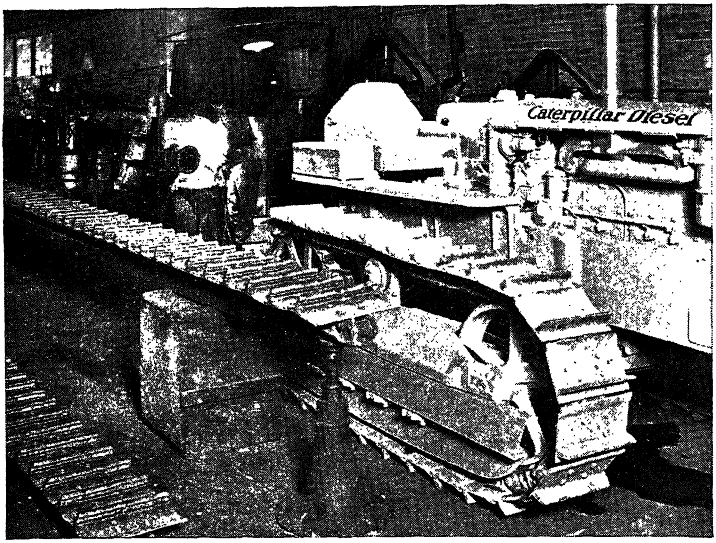


FIG. 187.—Building up and hard facing tracks and rollers. (*Courtesy of Lincoln Electric Co.*)

FIG. 188.—Building up track pad. (*Courtesy of Lincoln Electric Co.*)

to hammer, or, peen, each deposit while it is still malleable from the welding heat. Peening the deposit not only smooths the surface but packs the metal, or increases its density (Fig. 188).

FIG. 189.—Hard facing with the electrode recommended by the manufacturer. (*Courtesy of Lincoln Electric Co.*)

After the building-up process is finished, the wearing conditions that the surface or part will be subjected to must be known in order to select the correct hard-facing electrode. It is important to know whether the wearing action is to be abrasion or impact. A plowshare, for example, would be subject to abrasive wear, while a cable-tool drilling bit would be subject to impact.

There are electrodes available with full descriptions of their uses for each condition (Fig. 189).

The application of the hard material is made in the same manner as with the mild electrode. Additional information may be found on page 118.

CUTTING WITH THE ARC

Cutting with the arc is done by a reverse-polarity electrode, with the welding machine set on straight polarity with high voltage and high amperage. The explosive force of the arc under such conditions literally blasts the metal out of the line of travel.

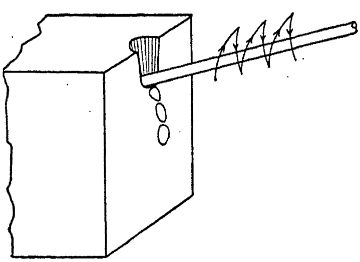


FIG. 190.—Arc cutting of cast iron. Arrows indicate motion of electrode.

Cutting with the arc is a speedy, economical method of veeing out cracks in castings preparatory to welding, dismantling castings, and cutting holes in plates. Cutting may be done with a carbon arc; but this only melts the metal out of the line of travel, does not have the digging power of the reverse-polarity rod, and is a slower process than that employing the metallic arc.

If a heavy casting is being prepared for bronze welding, the crack may be successfully veed out with the arc. This leaves a narrow, deep groove with roughened edges, ideal for bronze welding, and keeps to a minimum the amount of bronze rod necessary to fill the vee. With care, very thin castings may be veed out.

If possible, the cutting should be done in a vertical plane, cutting from the top down. Point the electrode straight into the puddle. Use a whipping stroke,

digging into the puddle deeply on the downstroke to wash the molten metal from the puddle (Fig. 190).

Do not try to cut too deep a groove with one pass. It is always better to make a second or even a third pass if necessary. The electrode should stand in water for several moments before cutting, to keep the flux from burning away during cutting and thus lowering the efficiency of the electrode.

In many instances, the broken parts of the casting are assembled and tacked with the cast-iron electrode.

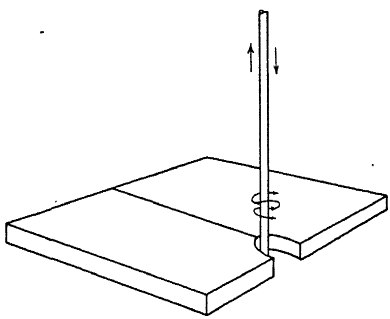


FIG. 191.—Arc cutting mild steel. Arrows indicate motion of electrode.

Then the reverse polarity is changed to straight polarity, a reverse-polarity mild-steel electrode is substituted for the cast-iron electrode, and the crack is veed out between the tacks. After the veed spaces are tacked, the uncut portion of the crack is veed out and tacked. This procedure aids greatly in maintaining perfect alignment.

The arc can be used to cut holes in cast-iron pipe, to install headers, or to cut broken cast valves or connections from steel pipe without injury to the threads. In this case, it is necessary to watch the cut closely to prevent nicking the threads and ruining the joint. If the casting is cut practically through, it may be broken and removed.

While a cut made with the arc is not so smooth or fast as one made with the acetylene cutting torch, nevertheless mild-steel plate may be cut to length or beveled for welding by this procedure.

In cutting a plate, the arc should be moved in a small half circle, cutting away the metal in the line of travel as it is advanced (Fig. 191).

If a hole is to be cut in a recess, the reflected heat will often overheat the cutting tip of an acetylene torch. With the arc process, the electrode is struck against the plate to be cut and as the puddle forms is forced entirely through the plate, leaving a hole about the size of the diameter of the electrode. If a larger hole is desired, move the electrode in a circle and widen the hole to any desired width.

CHAPTER XXI

TESTING WELD SAMPLES

The quality of a weld cannot be determined from its appearance. The surface may be rough and uneven, but the weld may be well fused into the joint, with good penetration. The top may be smooth and even, but the fusion and penetration into the joint may be very poor. The only positive method of determining the quality is to subject the weld to a series of tests, placing the metal under strains more severe than will ever be met in service.

The testing laboratories are fully equipped to subject the weld to rigid tests to determine its strength, ductility, and soundness. However, there are a series of tests that can be made in the shop or field, by the welder, to determine the quality of the weld. If the weld samples consistently pass the following tests, you may feel justified in assuming that you are well on the way to becoming a welder.

The first inspection of a fillet weld consists in examining the plates to see whether there are undercuts or rolled edges (Fig. 124). If these conditions are not present, the next step is to examine the inside of the weld, first to see whether there are full fusion and penetration along the joint, and second to determine whether the weld metal is clean and free from porosity or slag pockets. Slag pockets and porosity will occur if the beads are not properly cleaned between deposits.

Place the fillet weld in the vise with the unwelded edge of the joint turned up (Fig. 192). Hammer the

plate down to bend it away from the other plate. If the joint is poorly fused, this will be indicated by rough, blackened edges, with clean, gray metal along it here and there where good fusion was obtained.

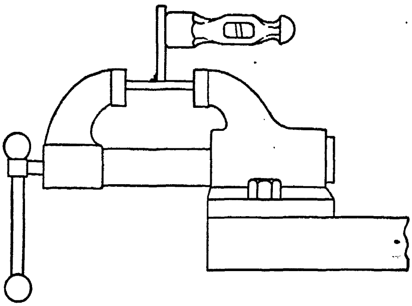


FIG. 192.—Testing fillet weld.

If the joint was bridged (Fig. 193), the bottom edge of the joint will be unbroken. If good fusion and penetration were obtained in the joint, a line of clean, gray metal will show along it.

Butt welds made with flat plates are tested by cutting samples across the weld about 1½ in. in width and about 10 in. in length (Fig. 194). In the testing laboratories the plates are machined on both sides to remove the weld metal on the top and bottom of the weld before testing. It will not be necessary for you to do this in a shop or field test.

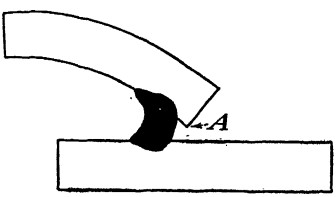


FIG. 193.—Fillet weld with poor penetration in throat: *A* indicates unbroken edge of vertical plate.

Cut samples from the butt weld, and allow them to cool normally; do not quench them in water to cool. A simple bender may be constructed with a hydraulic

jack (Fig. 195), or a hydraulic press may be used to test the samples (Fig. 196). If these are not available, then the test may be made in a vise. As this method is hard on the vise, make the tests only when you feel the samples are capable of passing them; do not test samples indiscriminately.

If the hydraulic jack is used (Fig. 195), place the sample, or coupon, under the rollers and over the heart-

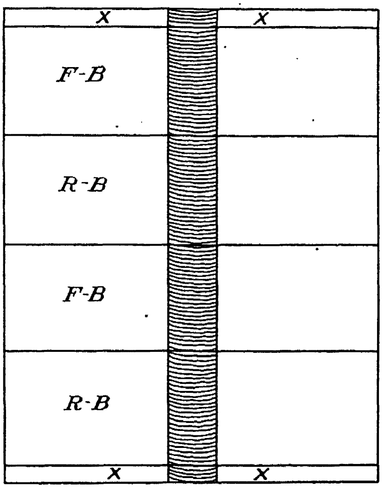


FIG. 194.—Butt weld marked for testing samples. *F-B*. Face bend. *R-B*. Root bend.

shaped slug on the ram, with the bottom or penetration side of the weld up. Jack the coupon completely through the rollers (Fig. 195). In order to adapt itself to the bend the penetration bead must stretch. If the weld is brittle, it will not bend. If there is poor penetration, the coupon will fracture. The penetration side of the coupon must show no fractures. If fracture does occur, no matter how little, count the test a failure. This test is called the *root bend test.*

The *face bend test* is made in the same manner except that the face of the weld is turned up as the coupon is forced through the rollers (Fig. 195). If any fracture occurs through the penetration bead, examine the coupon closely. You will discover that, although the weld metal protruded through the joint, it did not fuse

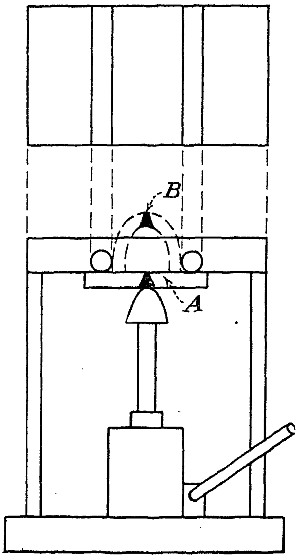


FIG. 195.—Weld-testing machine. *A*. Weld coupon. *B*. Dotted lines indicate coupon after bending.

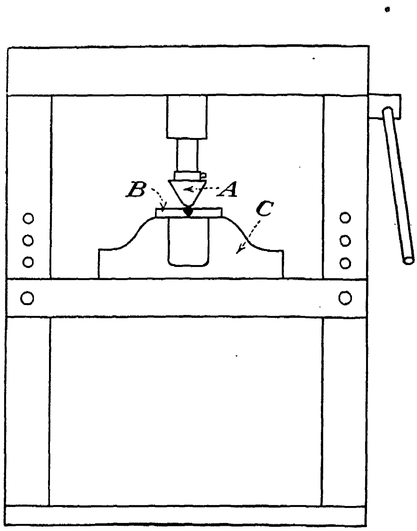


FIG. 196.—Hydraulic press used to test coupons. *A*. Heart-shaped piece of steel fastened to ram with setscrew. *B*. Weld coupon. *C*. Testing block.

into the joint, probably on the side next to the welder. When the next weld is made, keep this fact in mind and eliminate this condition.

The next test is the *nick-break test*. This is designed for inspection of the inside of the body of the weld. Cut the coupons from the pipe or plate as before. Cut into the weld from both edges, about $5/16$ in., either with a cutting torch or with a hack saw (Fig. 198). Heat

the weld and quench it quickly, making the weld brittle.

Place the coupon in a jig (Fig. 199), and strike it heavily with a sledge hammer. Nicking the coupon

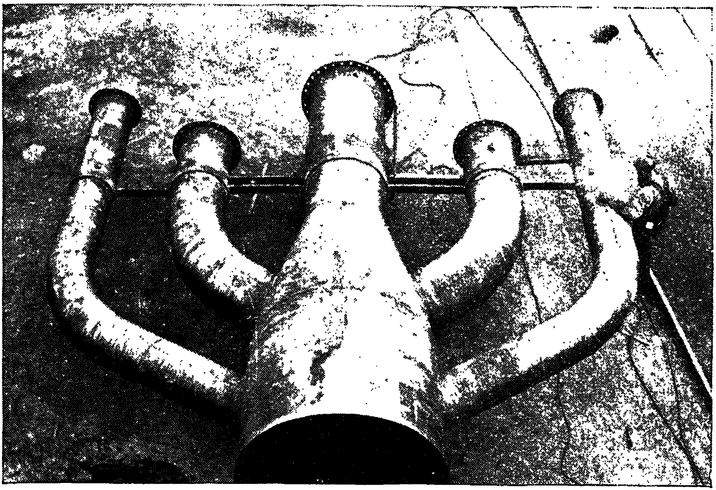


FIG. 197.—Making up a high-pressure manifold. (*Courtesy of Lincoln Electric Co.*)

plus the quenching will cause the coupon to snap in two pieces. Examine the interior of the weld metal closely for gas pockets or slag inclusion. Slag inclusion will be indicated by holes filled with black burned

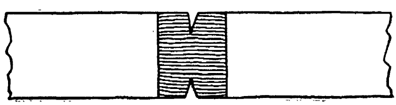


FIG. 198.—Weld coupon nicked for breaking.

material or a line of black slag running parallel with the weld. This slag line is generally between the first and second beads. The slag was not chipped out cleanly, nor was it floated out during welding. Continue

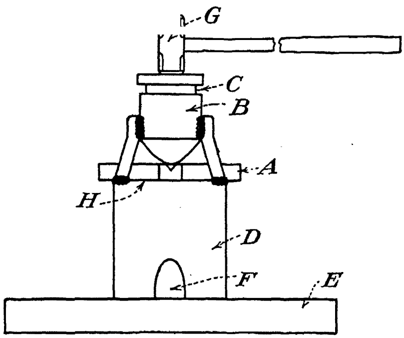


FIG. 199.—Machine for nick-breaking weld coupons. *A*. Weld coupon. *B*. Guide. *C*. Ram. *D*. Heavy-duty pipe. *E*. Steel base. *F*. Opening to remove coupon. *G*. Sledge hammer. *H*. Notch cut in pipe top to hold coupon.

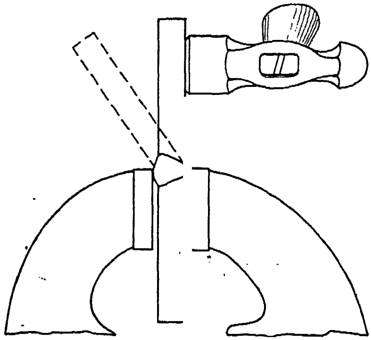


FIG. 200.—Testing weld samples in vise.

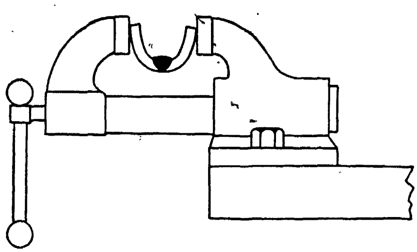


FIG. 201.—Completed bend of coupon in vise.

nick breaking weld samples until they are completely clean. Do not excuse the presence of a black spot in a break. Count the test a failure when this occurs.

When testing coupons in a vise, place the coupon in the vise in a vertical position so that the jaws of the vise meet in the center of the weld (Fig. 200). Use a heavy hammer, and strike the coupon near the vise, bending it back at about a 45-deg. angle. Bend the coupon back from the penetration side. Turn it upside down, and bend the opposite leg back in the same manner. Open the jaws of the vise wide enough to place the coupon in it to finish bending (Fig. 201). Tighten the vise slowly, adjusting the coupon so that it may bend evenly. Bend it in a full horseshoe. Examine it for fractures as before.

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